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SUMP PUMP STUDY

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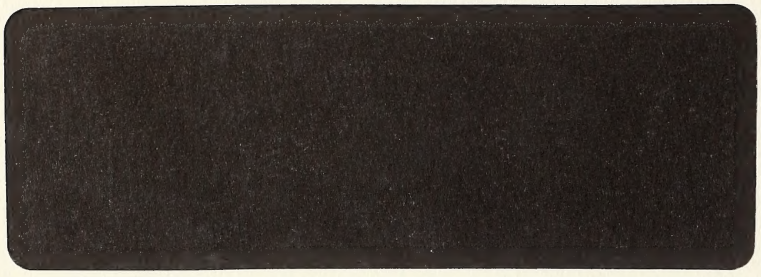

SUMP PUMP STUDY

OCTOBER 1991

Prepared by:

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The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

The Program offers assistance to builders, developers, consulting firms, professionals, industry groups, building products manufacturers, municipal governments, educational institutions, non-profit groups and individuals. At this time, priority areas for investigation include building design, construction technology, energy conservation, site and subdivision design, site servicing technology, residential building product development or improvement and information technology.

As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

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GLOSSARY OF TERMS

Source: 1) Handbook of Steel Drainage and Highway Construction Products (Canadian Edition) American Iron and Steel Institute
2) Manufacturer's Literature

BACKFILL: Earth or other material used to replace material removed during construction.

BACKFILL COMPACTION: Percent compaction (density) for backfill (required or expected).

COMPACTION: The densification of a soil by means of mechanical manipulation.

DATA LOGGER: A stand alone electronic storage device that records information on an assigned time interval.

DESIGN FREQUENCY: The recurrence interval for hydrologic events used for design purposes. As an example a design frequency of 50 years means a storm of a magnitude that would be expected to recur on the average of once in every 50 years.

DESIGN STORM: A precipitation event that, statistically, has a specified probability of occurring in any given year (expressed either in years or as a percentage).

DISCHARGE: The actual volume of water flowing from a drainage structure per unit of time.

DOWNLOAD: A complete memory transfer of all the data loggers memory to a disk file (computer) for diagnostic purposes.

DRAINAGE: Interception and removal of groundwater or surface water by artificial or natural means.

ENGINEERED SOIL: A selected soil of known properties placed in a prescribed manner.

FOUNDATION: That portion of a structure (usually below the surface of the ground) that distributes the pressure to the soil. Footing has similar meaning.

FOUNDATION DRAIN: A perforated pipe that collects groundwater from the foundation or footings for the purpose of draining unwanted waters away from such structures.

GRADE:	Refers to slope, or ratio of fall of rise or fall of the grade line to its length.
GROUNDWATER TABLE (LEVEL):	Upper surface of the zone of saturation in permeable soil.
HEAD:	The height of water (energy) above any plane or point of reference.
HYDROGRAPH:	A graph of runoff rate, inflow rate, or discharge rate versus time.
HYETOGRAPH:	A graph showing average rainfall, rainfall intensities, or rainfall volume over specified areas, with respect to time.
ICING:	The gradual accumulation of ice resulting from freezing water over a period of weeks or months.
IMPERVIOUS:	Impenetrable. Completely resisting entrance of liquids.
INFILTRATION:	The passage of water into the soil. The term is also used to refer to groundwater entering a sewer system through joints, manholes, etc. Infiltration is not usually desirable in sanitary sewer systems, but may be desirable in urban storm drain systems to control groundwater table and protect roadway pavements.
INFLOW:	The water discharged into a sewer system from all possible sources but not infiltration.
PERMEABILITY:	A property of soils that permits free passage of any fluid. Permeability depends on grain size, void ratio, shape, and arrangement of pores.
RETURN PERIOD:	The average period in years between occurrences of a discharge equalling or exceeding a given value.
ROOF LEADER:	A drain or pipe that conducts storm water from the roof of a structure downward and into a sewer for removal from the property, or onto or into the ground for seepage disposal.
SURCHARGE:	The flow condition occurring in closed conduits when the hydraulic grade line is above the crown of the sewer.

EXECUTIVE SUMMARY

Many existing sanitary sewer systems are not designed to handle significant foundation drain inflow, and basement flooding due to sewer backup has resulted. In the City of Edmonton and Strathcona County, bylaws prohibiting the discharge of foundation drain systems into sanitary sewer systems have recently been enacted for new or extensively renovated residences. Sump pump systems discharging effluent to the surface have become the most common means of complying with these enactments. The objectives of the study of sump pump systems for single-family and multi-family units are to identify the common problems and inconveniences of the existing systems, determine which issues may be resolved or mitigated in the design stages, and to field test system modifications and methods of improving system performance.

Sump pump system information was obtained by conducting telephone surveys, interviews, questionnaires, and field investigations. Homeowners, manufacturers, suppliers, builders, realtors, and municipal and provincial authorities were contacted for information and comments. Those contacted during the data-gathering phase were cooperative and many individuals continue to gather relevant information.

An analysis of the information obtained revealed the following:

- For single-family residences in neighborhoods where sump pump systems are mandatory, a minority of the systems are active (systems that convey foundation drainage on a regular basis).
- Of those that are active, the majority of systems are perceived by the residents to pose problems.

The most common problems identified in this study are summarized as:

- The sump pump discharge of water on sidewalks, roadways, and lawns that causes ice in winter and saturated lawns in summer.
- The fear that potential power and/or pump failure will result in basement flooding.
- The lack of standards, guidelines, and requirements for sump pump systems places the responsibility of system design on the homeowner or contractor.

- The homeowners' liabilities and responsibilities for a sump pump system in a multiple unit housing development are not clearly defined.

Sump pump discharge effects and the fear of power failure were the main concerns of homeowners and were the focus of the field testing program. The issues of standards and legal liabilities were the prevalent comments of the contractors, inspectors, and the legal sector. These issues were beyond the scope of this study.

Unlike framing, plumbing, and electrical systems, where there are established requirements that protect homeowners, the sump pump system is unregulated. Those interviewed stated that sump pump systems cross several regulatory boundaries including electrical, plumbing, and building codes and lot/subdivision drainage standards. With such a broad range of regulations, coordination of the development of a sump pump system standard will be a challenge.

Sump pump system performance may be improved with system modifications. The following system modifications were tested at the research facility:

- Two sizes of sumps
- A battery-operated, direct current (dc) sump pump
- Three onsite discharge alternatives that included surface discharge on landscaped areas, surface discharge to a constructed swale, and discharge to buried conduit

It was found during the testing program that:

- The sump pumps tested performed adequately
- Larger sump capacities provide protection in cases of power and/or pump failure
- The sumps should be lined
- Sump water discharge should be away from the backfill zone

The performance of sump pump systems of single-family detached dwellings and multi-family sites could be improved through system modifications and implementation of design

standards. The following recommendations are made:

- Sump pump capacity should be a minimum 1.5 L/s at 2.5 m total dynamic head
- Sump capacity should be site specific and the minimum sump volume should be 0.5 m^3
- Sump discharge should be defined as a point source of stormwater and be a planned component of the overall drainage plan

1.0 INTRODUCTION

Residential foundation drain systems collect significant volumes of storm water and groundwater. Typically, foundation drain systems have been connected to sanitary sewer systems for discharge of the influent water. Many existing sanitary sewer systems are not adequately designed to handle foundation drain inflow, and basement flooding due to sewer backup has resulted. In the City of Edmonton and Strathcona County, bylaws prohibiting the discharge of foundation drain systems into sanitary sewer systems have recently been enacted for new or extensively renovated residences. Sump pump systems, discharging effluent to the surface have become the most common means of complying with these enactments.

Reported problems with sump pump systems, such as ice buildup, wet yards, pump failure, lack of homeowner confidence, and general dissatisfaction with the systems, led to this study. This report documents the findings of the sump pump study.

1.1 Background

Various studies of inflow/infiltration (I/I) rates into sewer systems have identified foundation drain flows as a significant component of total flowrates. Foundation drain flowrates have been quantified in three previous studies and the results are summarized below:

Studies carried out in Winnipeg in 1972 (1,2) concluded that:

1. Foundation flowrates varied from a trickle to 0.45 L/s.
2. Thirty percent (30%) of the rainfall that falls on a house and backfill zone enters the foundation drain.
3. Homes with proper lot grading had only twenty-five percent (25%) of the flowrate of a home with poor lot grading.

The Ontario Study (3) measured the following drain flowrates:

1. The maximum hourly flowrate was measured at 0.544 L/s (1 960 L/h).
2. The daily maximum flowrate of 0.157 L/s (13 600 L/d) was recorded.

The Milwaukee Metropolitan Sewerage Division (MMSD) carried out an analysis of extraneous flows into sanitary sewers and the results regarding foundation flowrates are presented below (4).

1. The maximum 1-day volume was 0.064 L/s (5 530 L/d).
2. The average maximum hourly flowrate of foundation drains was 0.19 L/s (680 L/h).

These previous studies show that foundation drains contribute substantial volumes of flow into sewer systems. Where systems are overtaxed, needed capacity is gained when foundation drain flows are eliminated from the sewer system. In the City of Edmonton and Strathcona County sump pump systems discharge foundation flow to grade.

Sump pump systems are a relatively new component of the modern urban drainage system and many issues have yet to be addressed with respect to these systems.

1.2 Objectives

The objective of this study was to investigate the performance and effectiveness of sump pump systems discharging foundation drain flow to the lot surface of single-family detached dwellings and multi-family sites. The scope of work included:

1. A literature search
2. A review of regulatory requirements

3. An information survey of:
   - Homeowners
   - Municipal and provincial departments
   - Developers and builders
   - Manufacturers
   - Building inspectors
4. Site investigations
5. Evaluation of collected data and information
6. Identification of items that can be solved in the design stage
7. Field testing of proposed sump pump system improvements
8. Evaluation of the overall effectiveness of sump pump systems as a means of reducing inflow rates in sanitary sewers
9. Recommendations on the design, installation, and operation of sump pump systems.

1.3 Study Methodology

The study proceeded systematically through the tasks listed in the preceding scope of work. Items 1 through 4 were completed by January of 1991 and items 5 and 6 were addressed after the information was compiled and summarized. Field testing of proposed system improvements was completed by September 1991.

The data sources evolved as the information gathering phases progressed. Once the literature and regulatory reviews were concluded, questionnaires were completed by homeowners. Based on the homeowners' responses, the remaining sectors were surveyed by either personal interviews or mailed questionnaires.

The objective of the information survey was to document perceived

concerns and problems regarding sump pump systems along with the factual information. The first question in the single-family questionnaire is "Has your sump pump run for an unusual amount and if so, what was the weather condition?" This is a subjective question and a homeowner with an active sump pump, a sump pump that runs on average two or three times per day, has an entirely different connotation of an "unusual amount" than a homeowner whose sump pump rarely pumps water.

After the survey information was summarized, recurring comments and concerns were extracted from the data and evaluated. If the comment or concern could be addressed in the design phase, alternatives were sought; if the comments referred to regulatory/legal revisions, they were documented but not addressed further in this study.

The site investigations quantified sump dimensions, pump type, discharge rates, and discharge locations. The site investigations were used to substantiate information provided by homeowners and manufacturers.

1.4 Organization of the Document

This report is organized into eight ensuing sections and two appendices. Figures and photographs are presented immediately after the text page in which they are referenced. There is a detailed table of contents for each appendix.

1. Section 2.0 is a review of existing literature and practices for foundation drain discharge.

2. Section 3.0 is a review of regulatory requirements. Direct quotes from codes and statutes are presented in italics.
3. Section 4.0 discusses the data-gathering process and the information is summarized. Appendix A presents the detailed information.
4. Section 5.0 provides an analysis of the information obtained and an identification of the main concerns of homeowners and inspectors with sump pump systems.
5. Section 6.0 describes the field testing program carried out for the sump pump system improvements that were recommended. Field testing addressed possible solutions to the problems identified.
6. Section 7.0 presents the results of the field testing program. Appendix B contains the data record of the field tests.
7. Section 8.0 discusses the proposed modifications to the sump pump system.
8. Section 9.0 presents the conclusions and recommendations.

2.0 LITERATURE SEARCH

CH2M HILL ENGINEERING LTD. carried out a literature search for information similar to that in the study "Field Evaluation of Foundation Drain Response" (5). The documents found are the first four items listed in the bibliography. The database Engineering Index was further searched for articles from January 1988 to September 1990, but no additional information was found regarding residential sump pump systems or foundation drain response.

Findings of previous studies are summarized and presented below; the regulations are presented in Section 3.0. Current literature and regulations discuss the quantity of foundation drain flows and the collection of these flows. However, current literature does not discuss the issues of sump pump systems within the context of lot drainage and stormwater. Articles discuss sump pump systems as a solution for sanitary sewer inflows; however, their contribution to stormwater is not addressed. The City of Winnipeg, Ontario Ministry of Environment, and Milwaukee Metropolitan Sewage District have carried out an analysis of extraneous flows and all studies indicate that foundation drain flows constitute a significant component of the total sanitary sewer flowrates.

Review of existing practices for foundation drain discharge indicates municipalities throughout Canada and the U.S. deal with drain discharge by using various methods. CH2M HILL has reviewed weeping tile connection policies for 19 municipalities in Ontario. Of these, only two, Windsor and North York, allowed discharge to sanitary sewers. St. Catharines requires connection to storm sewers under normal circumstances; however, if this is not feasible, connection to sanitary sewers has been approved. The other 16 municipalities reviewed require connections to storm sewers, sump pumps, or third-line systems. The Ontario Ministry of the Environment and Ontario Municipal Engineers Association standards state that the connection of foundation drains to sanitary sewers is discouraged or not

recommended.

Other jurisdictions surveyed include Winnipeg, which requires sump pits with sump pumps in all buildings with basements installed since 1987. Foundation drain flows are discharged at grade. In Chicago, foundation drains are required to be connected to sump pumps with discharge to storm sewer systems or drainage ditches.

In the City of Edmonton, the requirements for foundation drain discharge have changed over time. In the City's design guidelines for 1972, 1974, 1976, and 1982, foundation drains were to be connected to the sanitary sewer system. In the 1986 guidelines, weeping tile discharge locations are listed as sanitary sewers, storm sewers, or ground level via sump pump. The 1988 standard disallows foundation drain discharge to sanitary sewers.

2.1 Review of Previous Tests

Where foundation drains are connected to the sanitary collection system, the quantification of resulting flows has been frequently investigated and, in several instances, field tests carried out. Studies carried out by various municipal and provincial organizations in three areas to investigate the topic are reviewed and summarized below.

2.1.1 Winnipeg

Studies carried out in Winnipeg (1,2) were directed at determining the magnitude of flows, the relationship between weeping tile flows and rainfall, the effects of on-lot practices, and the contribution from roof leader flows. Seven lots were observed.

The program was intended to focus on natural rainfall events.

However, the rainfall for the year (1972) was lower than normal and additional testing involving roof leader flows was carried out. Uniform rates of flow were applied to roofs and the results recorded. The rates and discharge locations were varied.

The on-lot apparatus consisted of a pump with an electronic strip chart recorder. A network of seven municipally operated raingauges was used to determine rainfall at the particular sites. Each test site had one raingauge in its area.

Following is a summary of test results:

- Time lapse from start of rainfall to start of drain flow varies from zero to more than 1 hour.
- Peak flows varied from a trickle to 0.45 L/s.
- Lag time is a characteristic of each individual lot but is also very dependent on antecedent condition.
- Results indicated that lot grading conditions adjacent to the homes have a significant impact on foundation drain flows.
- The roof flow simulations led to the conclusion that the roof flows generate the majority of foundation drain flows (60 percent). Thirty percent of the rainfall that falls on the house and the dished area around the house, typically resulting from settled backfill material, enters the weeping tile.
- This study did not address soil characteristics nor did it consider a model for correlation of predicted flows to actual flows.
- Over a longer period, say 24 hours, as much as 50 percent of the total roof volumes was estimated to enter the foundation drains. In addition, it was estimated that 10 percent of the total runoff from entire areas is conveyed to sanitary sewers.

- Homes with proper lot drainage had only 25 percent of the flowrate of those with poor lot grading.

2.1.2 Ontario

Studies were carried out by the Ontario Ministry of the Environment to assess the quantity and quality of foundation drain water (3). Information was gathered on foundation drain weeping tile flows as affected by a number of parameters, including:

- Soil type
- Backfill slope
- Weeping tile
- Roof drainage

The study consisted of five residences in Ontario, each equipped with a tipping bucket raingauge on the roof and a pump recorder on a sump pump. Two additional locations, where the apparatus was initially tested, were also analyzed. Technical problems were encountered and as a result not all records are complete. In addition to rainfall-related flows in foundation drains, the effects of snowmelt were examined.

The study notes the following:

- In response to rainfall, a maximum hourly drain flow of 1960 L was measured.
- In response to rainfall and snowmelt, a daily maximum flow of 13,600 was measured.
- Direct relationships between rainfall and foundation flows could not be established.
- The extreme case noted resulted in foundation drain flows

accounting for 20 percent of annual sanitary flows where the foundation drain was connected to sanitary sewers. General cases suggest 6 to 10 percent. Thus, even the general case figures have an impact on conveyance and treatment costs.

2.1.3 Milwaukee

As part of an inflow/infiltration (I/I) study, the Milwaukee Metropolitan Sewerage Division (MMSD) carried out an analysis of extraneous flows into sanitary sewers (4).

The on-lot portion of the study used a group of homes along a two-block stretch, as well as homes scattered throughout the rest of the city. Participation by homeowners was voluntary. Each home studied had metering equipment installed to monitor:

- Water consumption
- Flowrates in sewer service connections
- Flowrates from sump pumps connected to foundation drains

If the home selected had no sump pump, one was installed at no cost to the homeowner. Sewer service lateral line repairs, if required, were also carried out at no cost.

Field testing consisted of:

- Rainfall simulations
- Smoke and dye testing of sewer service lines to check for leakage
- Foundation drain flooding using hoses at ground level

The maximum measured foundation inflow flowrates for various time

periods indicated large variations. The average rates for 31 sites were:

1 hour	0.10 L/s	(1.6 USgpm)
1 day	0.012 L/s	(280 USgpd)
2 days	0.009 L/s	(210 USgpd)
3 days	0.007 L/s	(150 USgpd)
7 days	0.004 L/s	(100 USgpd)

The maximum recorded 1-day flowrate was 0.064 L/s (1,460 USgpd). The MMSD study notes the following points:

- The average maximum hourly I/I from sump pumps and foundation drains connected to sanitary sewers was 0.189 L/s (3 USgpm).
- I/I rates observed from sump pumps and foundation drains varied significantly, but homes in clayey type soil and those with positive drainage or in elevated and terraced lots had lower I/I rates.

3.0 REVIEW OF REGULATORY REQUIREMENTS

Canadian codes, standards, acts, regulations, and guidelines of various agencies and jurisdictions were reviewed. The following excerpts from the various regulatory documents indicate the requirements for foundation drains and sump pump systems.

3.1 National Building Code, Residential Standards 1980 (10) Section 14 Drainage:

E. Drainage Disposal

(1) Drain pipe or tile shall drain to a sewer, ditch or dry well.

(2) Where a sump pit is provided, it shall be at least 750 mm in depth and have an area of at least 0.25 m^2 and be provided with a cover. Where gravity drainage is not practical, an automatic sump pump shall be provided to discharge the water into a sewer, drainage ditch or dry well.

(3) Dry wells may be used only when located in areas where the natural groundwater level is below the bottom of the dry well. Dry wells shall be not less than 5 m from the building foundation and located so that drainage is away from the building.

In Alberta, the Residential Standard was replaced by the Alberta Building Code (Circa 1984); it was the accepted standard for the housing industry during the early 1980s. The Residential Standard was a reprint of sections of the Alberta Building Code that regulated residential construction. It provided builders with information on minimum drain pipe diameter (100 mm) and sump size. The minimum sump pit size specified was the overall sump dimension and did prescribe the sump capacity, which depends on the relative elevations of the incoming foundation drain pipe and the pump inlet (refer to Figure 1, Page 17).

3.2 National Building Code 1985 (11)

The National Building Code 1985 (11), Subsection 9.14.2 Drainage, General, Subsection 9.14.5 Drainage Disposal and Subsection 9.14.6 Surface Drainage and the Alberta Building Code 1985 (12), enact the same requirements and are quoted below.

> *Subsection 9.14.2 General*
>
> *9.14.2.1 Unless it can be shown to be unnecessary, the bottom of every exterior foundation wall shall be drained by drainage tile or pipe laid around the exterior of the foundation in conformance with Subsection 9.14.3 or by a layer of gravel or crushed rock in conformance with Subsection 9.14.4.*
>
> *Subsection 9.14.5 Drainage Disposal*
>
> *9.14.5.1 Foundation drains shall drain to sewer, drainage ditch or dry well.*
>
> *9.14.5.2 Where a sump pit is provided, it shall be at least 750 mm in depth, 0.25 m^2 in area and be provided with a cover. Where gravity drainage is not practical, an automatic sump pump shall be provided to discharge the water into a sewer, drainage ditch or dry well.*
>
> *9.14.5.3 Dry wells may be used only when located in areas where the natural groundwater level is below the bottom the dry well. Dry wells shall be not less than 5 m from the building foundation and located so that drainage is away from the building.*

Subsection 9.14.6. Surface Drainage

9.14.6.1 The building shall be located or the building site graded so that water will not accumulate at or near the building.

9.14.6.2 Surface drainage shall be directed away from the location of a water supply well or septic tank disposal bed.

9.14.6.3 Where runoff water from a driveway is likely to accumulate or enter a garage, a catch basin shall be installed to provide adequate drainage.

9.14.6.4 Where downspouts are provided and are not connected to a sewer, provisions shall be made to prevent soil erosion.

An official interpretation of subsection 9.14.5 Drainage Disposal was requested in 1988, from the Building Standards Branch, Alberta Labour and the reply referencing its interpretation and jurisdiction is as follows:

Regarding interpretation, section 10 of the Interpretation Act required that "an enactment", "shall be given the fair, large and liberal interpretation that best ensures the attainment of its objects".

Regarding code jurisdiction, in this question, the code is restricted in the application to the property on which the building is built. The collection and disposal of water when it leaves the property is a municipal responsibility.

The object of the requirement is to remove the subsurface water that accumulates to ensure structural stability and to prevent water entry

that would cause damage and health and safety threats.

9.14.5.2 states:
Where gravity drainage is not practical, an automatic sump pump shall be provided to discharge the water into a sewer, drainage ditch or dry well.

The sewer should be interpreted as a building drain or a storm drain and these are clear cut. A drainage ditch properly constructed to be more than a swale to handle surface drainage is an acceptable means of removing the water to a municipal collection system. The design of the ditch must relate to the volumes of water it is expected to accommodate including both surface and sub-surface water. To help prevent recirculation of ground water, there should be no standing water within 5 m of the foundation and drainage must be directed away from the foundation. Drainage ditches should not pass over excavated and back filled areas around foundations. A dry well, 5 m from the foundation that drains away from the foundation may be used where the water table is below the bottom of the dry well.

Pumping sub-surface water from the foundations to the surface is not an acceptable solution as it would promote recirculation leading to a build-up problem at the foundation.

The direct questions raised are whether or not the pumped drainage can be permitted to discharge to any of the following points:
a) the landscaped yard away from the building (1.5 meters minimum),
b) on-lot swales which drain the property,
c) the fence line, where a drainage swale follows the fenceline,
d) a disconnected storm roof leader extension pipe or splash pad,

where the outlet end of the pipe or pad is 1.5 meters away from the building.

Ruling (February 15, 1988 Building Standards Branch, Alberta Labour):

1. *Pumped water from the foundation drainage system cannot be discharged to the landscaped yard away from the building (1.5 meters minimum).*
2. *Pumped water from the foundation drainage system cannot be discharged to on-lot swales designed for surface drainage of the property. However, a properly designed drainage ditch sized to accommodate both surface and sub-surface water is an acceptable part of a drainage system for pumped water in the Code.*
3. *The swale along the fence line falls into the same category as item 2 and is only acceptable if properly designed as a drainage ditch sized to accommodate both surface and sub-surface water.*
4. *It would not be acceptable to discharge pumped water from the foundations to a disconnected storm roof leader extension pipe or a splashpad where the outlet end of the pipe or pad is 1.5 meters minimum away from the building.*

The foregoing rulings, 1 through 4, define where the pumped drainage can be discharged to surface. The pumped drainage must be discharged 1.5 m minimum away from the building to an on-lot designed drainage ditch sized to accommodate both surface and subsurface water. It must be noted that the ruling did not address discharge to the sewers.

The ruling specifies that sump pumps discharging to surface must discharge into a designed drainage ditch; however, the service level (design storm event) for the drainage system was not addressed.

3.3 The Canadian Plumbing Code 1990 (17):

Appendix A - 4.5.3 Subsoil Drainage Connections

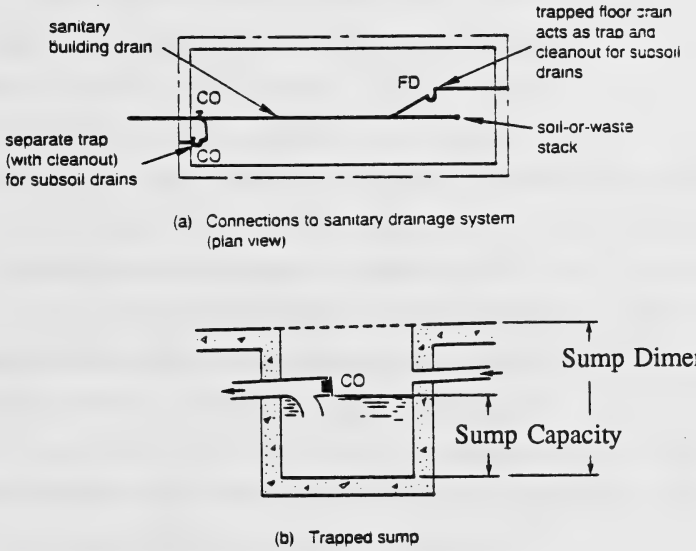


Figure 1 SUMP DETAILS CANADIAN PLUMBING CODE 1990

This Code does not regulate the installation of subsoil drainage pipes, but does regulate the connection of such pipes into the plumbing system. The intent of this article is to place a trap between the subsoil drainage and pipe and the sanitary drainage system. The cleanout must be installed in accordance with sentence 4.7.1.(2). A trap or sump may be provided

specifically for the subsoil drains, or advantage may be taken of the trap of a floor drain or storm water sump as shown above (Figure 1).

3.4 Alberta Regulation 410/87, Plumbing and Drainage Act 1987 (14) Alberta Plumbing and Drainage Act, Division 2, Subsoil Drains:

To be protected from backflow

108 Every subsoil drain shall be protected from the backflow of sewage, sewer gases or storm drainage water.

Connection to building drain or sewer

109 Where a subsoil drain is directly connected to sanitary building drain or building sewer or a combined building drain and building sewer, the connection shall include accessible and approved

(a) trapped backwater valve, or

(b) a separate trap and backwater valve.

Connection to storm drainage system

110 When a subsoil drain is connected to a storm drainage system, the connection shall include an accessible backwater valve.

Sumps

111 (1) Where a subsoil drain runs into a sump, the water may be removed from the sump by means of

(a) a pump, or

(b) a connection described in section 109.

(2) a subsoil seepage drain connection to a sump shall be made in a manner that prevents backflow from the sump to the sub-soil seepage piping.

The Act describes the subsoil drain system. It does not provide regulations or standards for the sump and sump pump.

3.5 Chapter P-10 Revised Standards of Alberta Plumbing and Drainage Act 1980 (15):

The Statutes outline the authority of an inspector. The Statutes allow an inspector to enforce the Act, but the established acts and regulations do not regulate sump pump systems; therefore, the inspector may recommend system improvements. (At the time of writing this statute was under revision.)

3.6 Lot Grading Guidelines, City of Edmonton 1989 (16):

4. Sump Pumps

Sumps and pumps should be installed to collect weeping tile flows and discharge these flows to grade. Please note that weeping tiles cannot be connected to the sanitary sewer under the Sewer Bylaw. It is essential that an effective maintenance program be conducted by the homeowner to ensure that the above features are appropriately maintained.

The sump should discharge onto a splash pad and drain away from the house along a possible drainage course in accordance with Alberta Building Code Requirements.

The Building Inspection Branch of the City of Edmonton provides illustrations within the Lot Grading Guidelines for weeping tile connections and typical installation, and sump pump connection (Figures 2 and 3).

3.7 Strathcona County

Strathcona County has two bylaws that deal with related issues; the Sewer Bylaw and the Property Drainage Bylaw. However, it is the 1984 Motion of

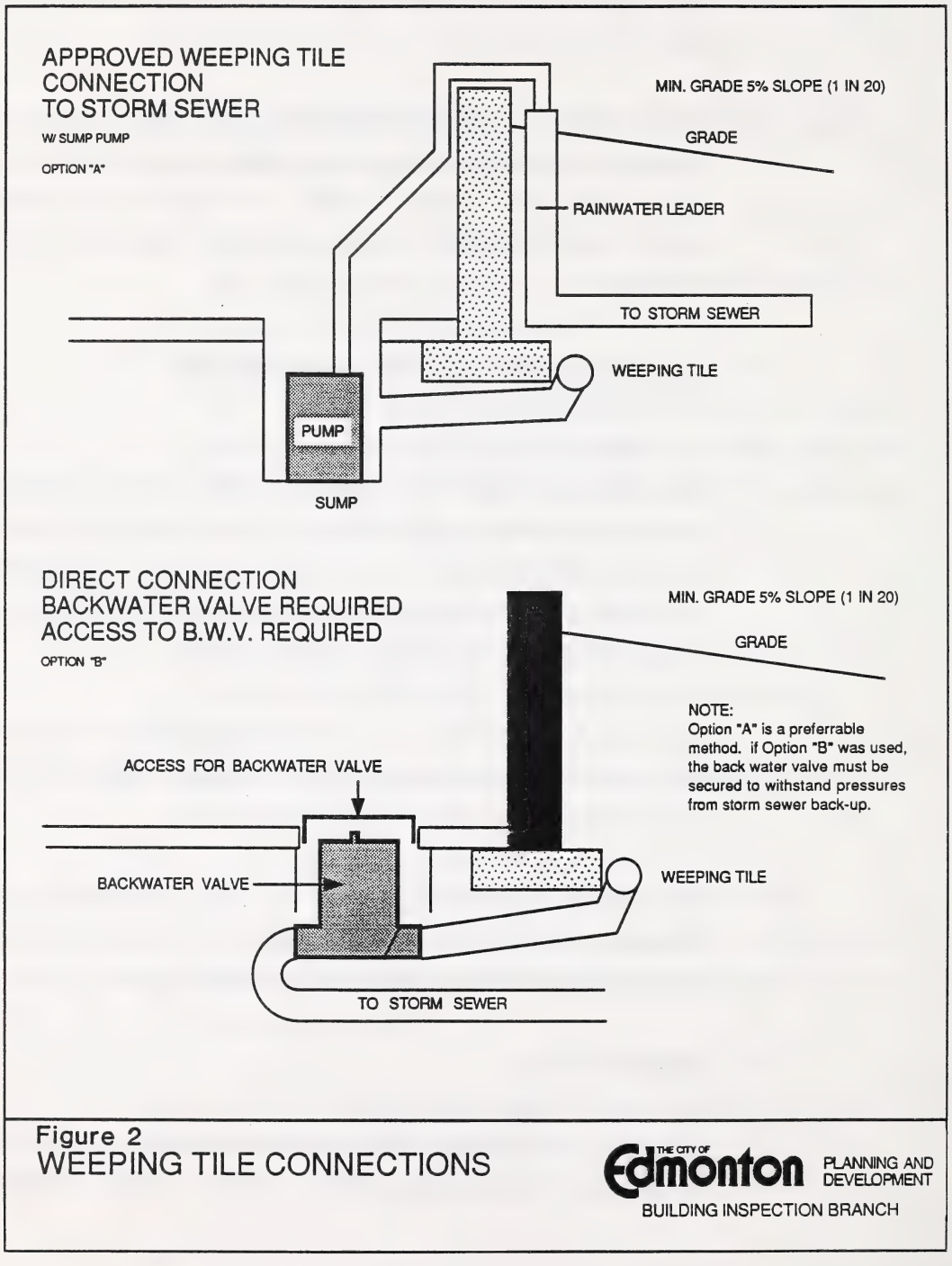


Figure 2
WEEPING TILE CONNECTIONS

THE CITY OF Edmonton PLANNING AND DEVELOPMENT
BUILDING INSPECTION BRANCH

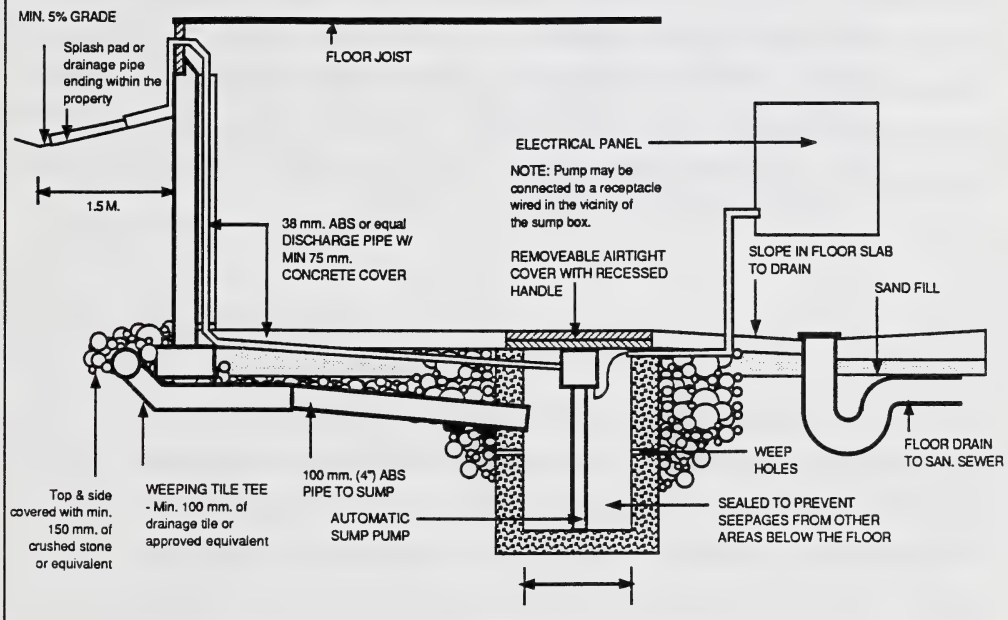

MIN. 5% GRADE
Splash pad or drainage pipe ending within the property
FLOOR JOIST
ELECTRICAL PANEL
NOTE: Pump may be connected to a receptacle wired in the vicinity of the sump box.
1.5 M.
38 mm. ABS or equal DISCHARGE PIPE W/ MIN 75 mm. CONCRETE COVER
REMOVEABLE AIRTIGHT COVER WITH RECESSED HANDLE
SLOPE IN FLOOR SLAB TO DRAIN
SAND FILL
WEEP HOLES
FLOOR DRAIN TO SAN. SEWER
Top & side covered with min. 150 mm. of crushed stone or equivalent
WEEPING TILE TEE - Min. 100 mm. of drainage tile or approved equivalent
100 mm. (4") ABS PIPE TO SUMP
AUTOMATIC SUMP PUMP
SEALED TO PREVENT SEEPAGES FROM OTHER AREAS BELOW THE FLOOR
Min. 500 MM X 500 MM (approx. 20" X 20") FOR SQUARE PITS
approx. 600 MM (24") DIAM.FOR ROUND PITS
Depth of Sump Pit - 750 mm. (30")
MIN. AREA OF SUMP - 0.25 M²
PLACE SUMP ON UNDISTURBED SOIL
SUMP PIT MAY BE CONSTRUCTED OF:
a) Concrete
b) G.M.V. Steel
c) Pressure treated wood
d) Approved A.B.S. or P.V.C. or equal
CODE REFERENCE ON SUMP:
ALBERTA BUILDING CODE ART: 9.14.5.2

Figure 3
TYPICAL INSTALLATION
SUMP PUMP CONNECTIONS

THE CITY OF Edmonton PLANNING AND DEVELOPMENT
BUILDING INSPECTION BRANCH

Council disallowing the connection of foundation drains to sanitary sewers that regulates foundation drain flows. The foundation drain discharge requirement is incorporated into the development agreement executed between the developer/builder and the County. County officials have commented that this method of conformance has been successful.

The regulatory requirements, codes, and acts do not suggest standards nor do they regulate sump pump systems. For example, the codes and regulations do not provide a standard for sump pump systems similar to the standards established for a framing system or a plumbing system. The code states a minimum sump size but not a minimum sump capacity. Currently, standards for residential sump pump system design and installation are not in place.

4.0 INFORMATION SURVEY

During the data-gathering process CH2M HILL contacted homeowners, manufacturers, suppliers, builders, realtors, and municipal and provincial authorities. The information was gathered by random selection but the sample size was not large enough to reduce statistically. The names of individuals and private companies have been withheld to allow anonymity. The problems, opinions, and facts gathered are considered representative for this study. The sectors contacted during the data-gathering phase were cooperative and many individuals continue to gather relevant information. Survey summaries are presented in Appendix A. The following sections present descriptions of the procedures, responses, and the significant information gathered from the different groups.

4.1 Residential Sectors

Information and opinions regarding sump pump systems were gathered from single-family and multi-family homeowners. As defined by Canada Mortgage and Housing Corporation, single-family sites were detached dwellings and multi-family sites were block town-housing developments. The single-family sites were located in Strathcona County and the multi-family sites in the City of Edmonton.

4.1.1 Single-Family Dwellings

Homeowners of single-family dwellings with sump pumps were surveyed by telephone in the fall of 1990. A public notice was placed in the Sherwood Park Booster published on October 14, 1990 (Figure A-1) advising residents of the planned survey. The questionnaire (Figure A-2) was designed to obtain information regarding operation and maintenance requirements and a general opinion of sump pump

systems.

It was expected that the newspaper advertisement would produce approximately 40 voluntary responses; however, only one resident replied to the public notice. Consequently, an additional 47 homeowners were telephoned directly; 40 agreed to complete the interview. They were selected by using the telephone directory to choose addresses within new subdivisions. The survey was conducted between the hours of 7 and 9 p.m. on weekdays. Each of the questionnaires took approximately 10 to 15 minutes to complete.

Of the 40 respondents, nine homeowners have installed bypasses directly into the sanitary sewer. The bypasses are connected during the winter months. Within the group surveyed, two homeowners had sump pumps replaced and one homeowner had the float mechanism replaced. A replacement sump pump and installation varies from $140 to $400, depending on the type. Float (switch) replacement varies from $35 to $85.

Based on the interviews, few of the respondents (approximately 20 percent) had problems with their sump pump systems. Of the homeowners who had concerns, the common ones were:

1. The fear of power failure during rainstorms
2. Uncertainty regarding pump reliability
3. Uncertainty regarding needed maintenance
4. The discharge water killing grass in the summer
5. The discharge water freezing on sidewalks and roadways in the winter

Photographs 1 and 3 are typical residential sump pump installations.

The installations are commonly a sump pump with 1.2 to 2.2 L/s discharge at 2.4 m total head placed within a plywood-lined sump pit of 0.22 m^3 total volume, with a 38-mm discharge pipe to a concrete splash pad (photos 4, 6, and 7). Photographs 4 and 8 show typical problems caused by discharge water. Photograph 4 is a picture of saturated ground at the splash pad and Photograph 8 shows ice buildup on the road caused by sump discharge water.

Photographs 1 through 11 are presented to show typical installations and problems.

Photo 1 - Typical Sump Pump This shows a typical sump pump installation showing inlet and discharge pipe, pump and float, and treated plywood sump pit liner. Approximately 200 mm of standing water is in the sump.

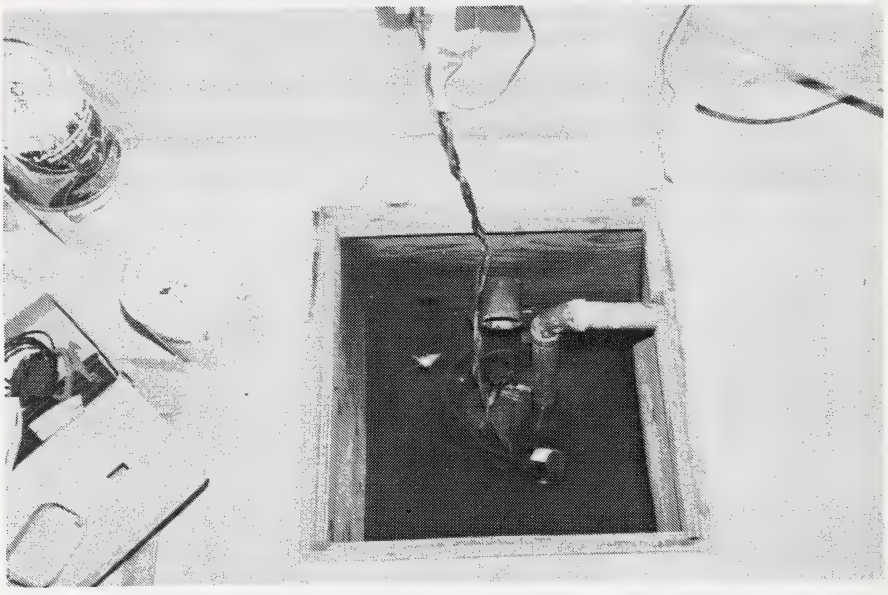


Photo 2 - Two Pump System This is a sump pump system with two pumps. The pump at the lower right acts as a backup. This homeowner experienced basement flooding with the original single sump pump.

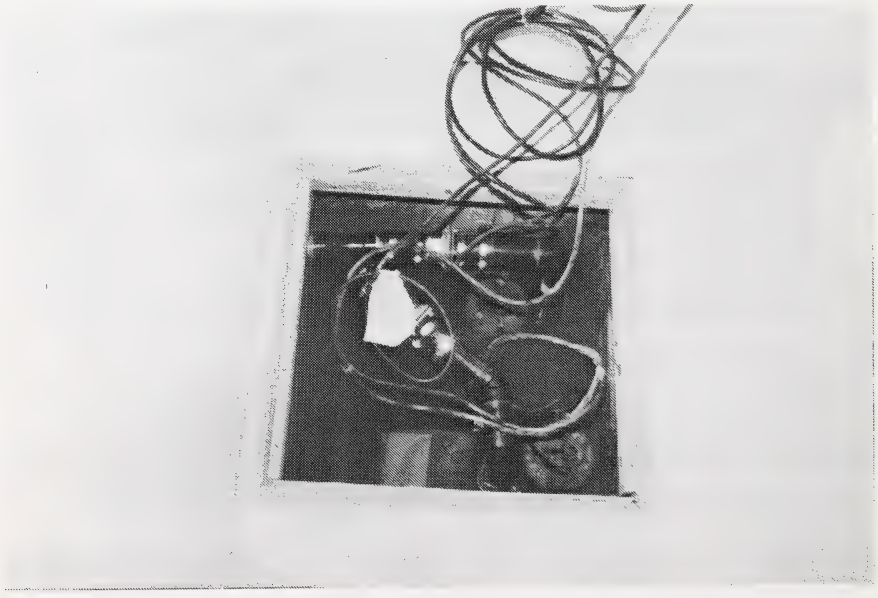


Photo 3 - Dry Sump Pit This sump pump system was dry and has only run a few times in a 2-year period. The pipe in the lower right corner is either a vent and/or overflow.

Photo 4 - Discharge Hose The homeowner has attached a flexible hose on the pump discharge to vary the location of discharge water to minimize ice buildup of this extremely active sump pump system.

Photo 5 - Typical Multi-family Site This photograph illustrates the site layout of the block townhousing developments investigated.

Photo 6 - Sump Discharge Location This picture shows a sump pump discharge pipe with a 90° bend to direct water to the front yard. The splash pad has been moved to the roof leader.

Photo 7 - Sump Discharge Location The photograph illustrates a typical active sump discharge arrangement.

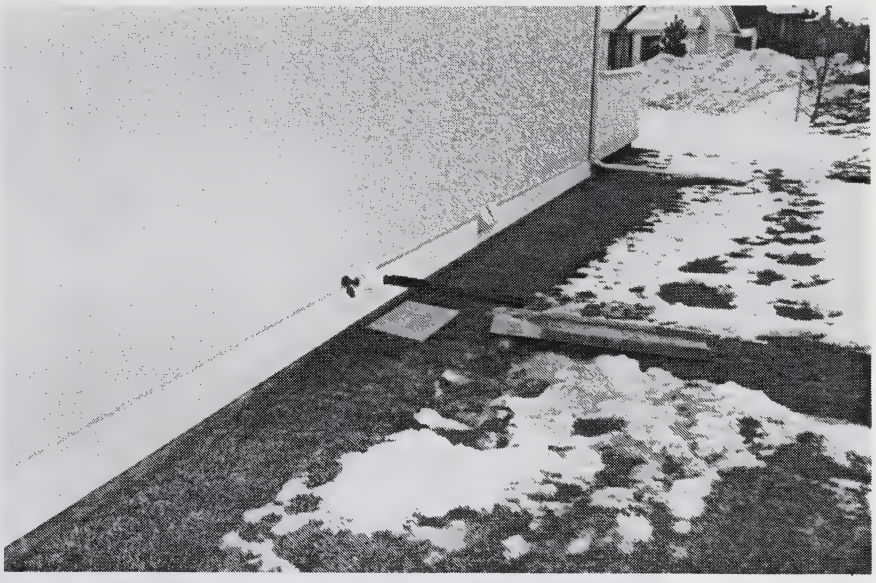


Photo 8 - Ice Buildup The ice buildup on the street can be attributed to the sump discharge water. The roof leaders at this location cause negligible ice buildup.

Photo 9 - Drop Curb A drop curb is provided to allow the landscaped swale to discharge to the street. Immediately adjacent to the roof leader on the sideyard is a sump discharge.

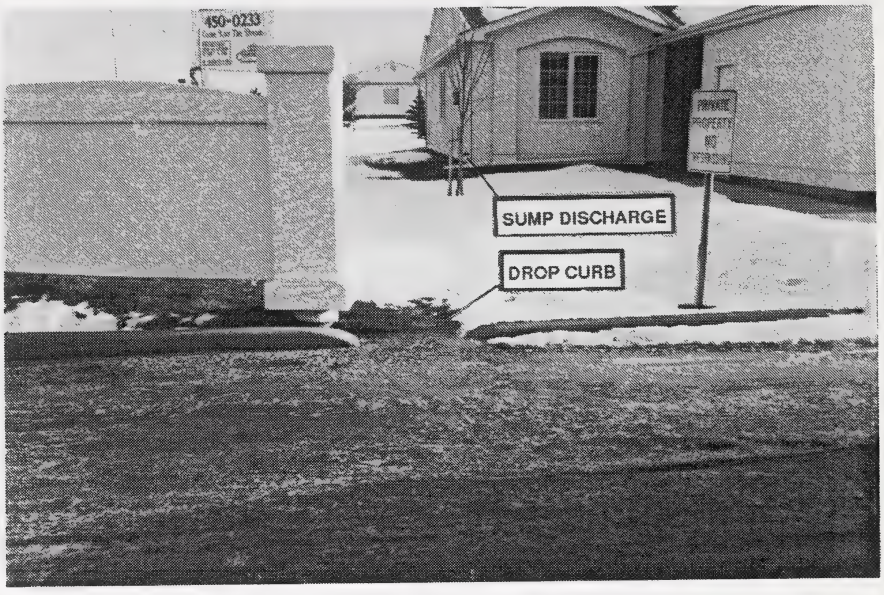


Photo 10 - Roof Leaders Because of the current architectural style of roof lines, multiple roof leaders are needed to discharge eaves troughs.

Photo 11 - Ice Buildup Roof leader discharge is a significant contributor to the ice buildup on the interior roadways.

4.1.2 Multi-Family Sites

The two multi-family sites investigated in the study were selected by the City of Edmonton from a list of recent developments. Sites were selected that did not have known extreme conditions of any type in order to maximize the applicability of the findings to other developments. Both sites are bungalow-style block townhousing developments and both sites are termed adult villages (the occupants are 45 years of age and older). The site layout and building densities in the two developments are similar, as illustrated in Figures 4 and 5.

After the sites were selected, the developers and condominium associations were contacted by telephone to discuss the study objectives and to obtain approval for site investigations. A preliminary site visit was conducted to determine the specific sump pump issues of

multi-family sites compared to single-family dwellings. Following the initial site investigation, 15 homeowners within the developments provided information on the costs of operation and maintenance, on problems they have experienced, and provided their opinions on the effectiveness of sump pump systems.

The sump pump systems for the multi-family sites were the same as the systems for single-family dwellings. The installations were similar in piping, sump dimensions, pump installations, wiring, and discharges.

The major problem identified by multi-family site homeowners was the effect of sump pump discharge water. The units with active sump pumps caused saturated lawns in the summer months and ice on sidewalks and roadways in winter. A detailed site inspection to locate discharges (Figure 4 and Figure 5) and identify icing problems was conducted on January 25, 1991. Photographs 8 and 11 show the icing conditions. The site investigation reports are included in Appendix A.

The detailed site investigation verified that ice buildup occurs. Heavy ice buildup on landscaped areas, roadways, and walks was observed. Some sump pump systems were disconnected. Other foundation drains were connected to the sewer. Where foundation drains were connected to the sewer, roof leader discharge still caused icing of roads and sidewalks. Claims of saturated lawns could not be verified because the inspections were conducted in the winter months.

Developers, contractors, plumbing inspectors, building standards representatives, and lawyers were interviewed by telephone regarding multi-family site sump pump systems and these interviews are summarized in the following sections.

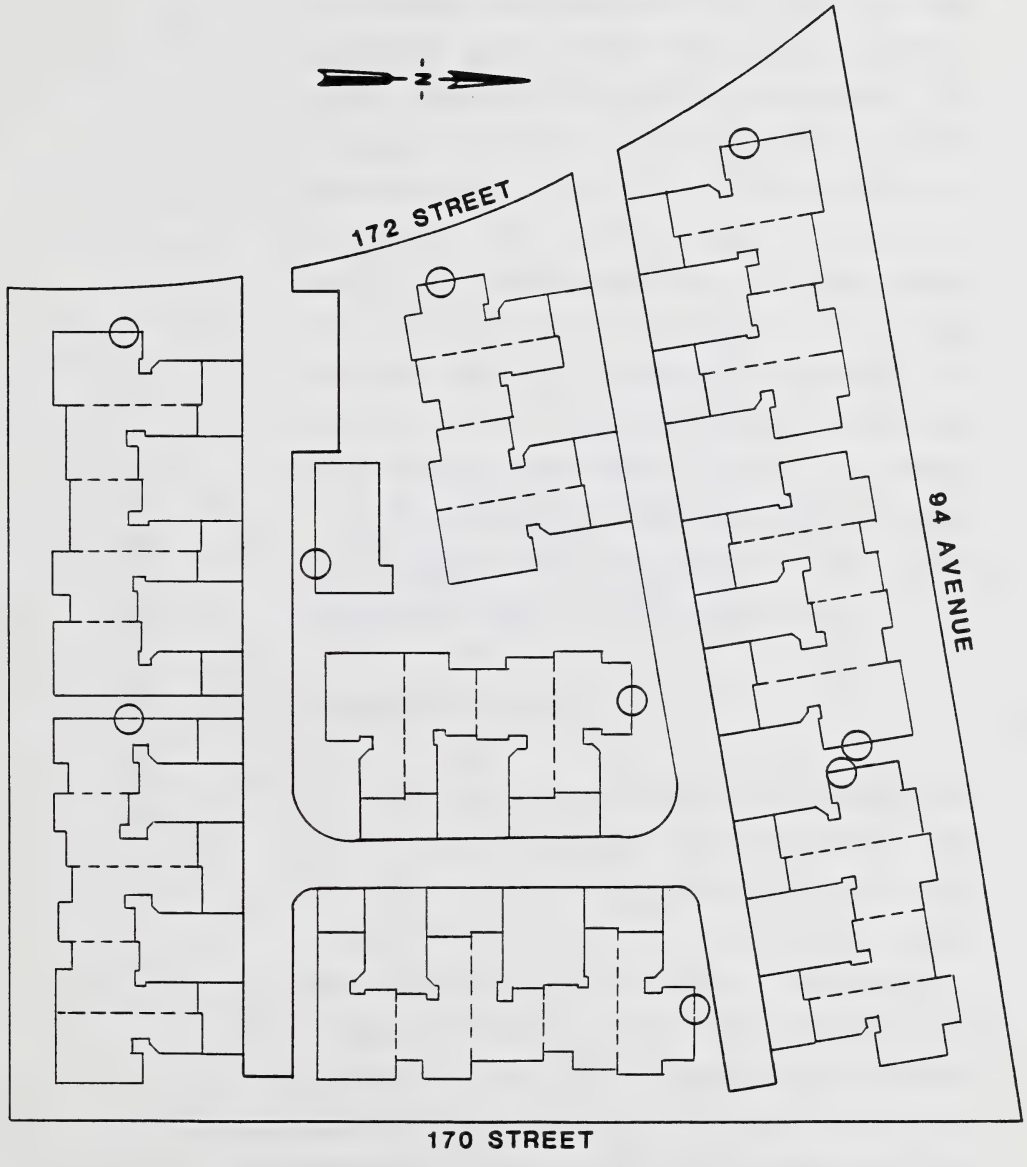


Figure 4 CARRINGTON VILLAGE SITE LAYOUT

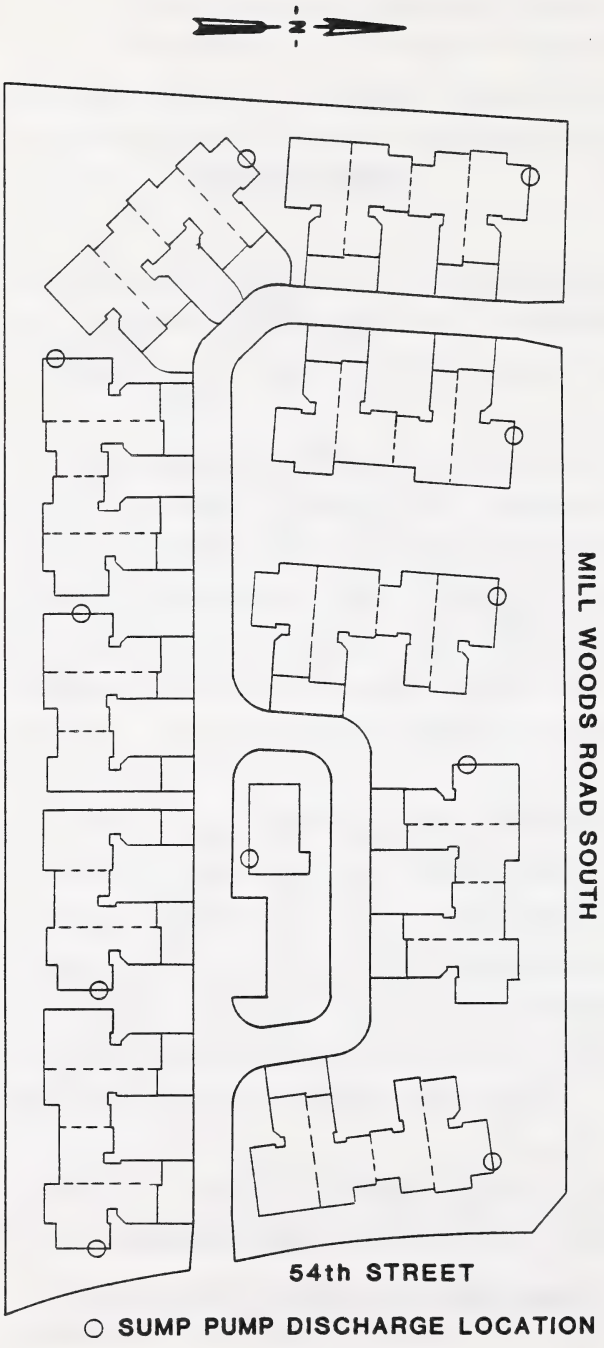


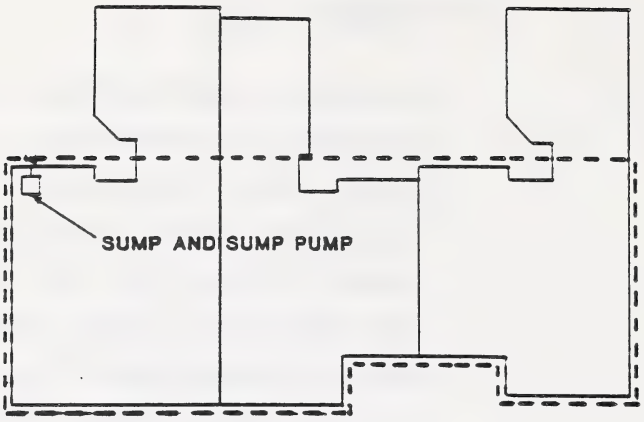
Figure 5 THE SPRINGS BY CARRINGTON
SITE LAYOUT

4.1.2.1 Developers

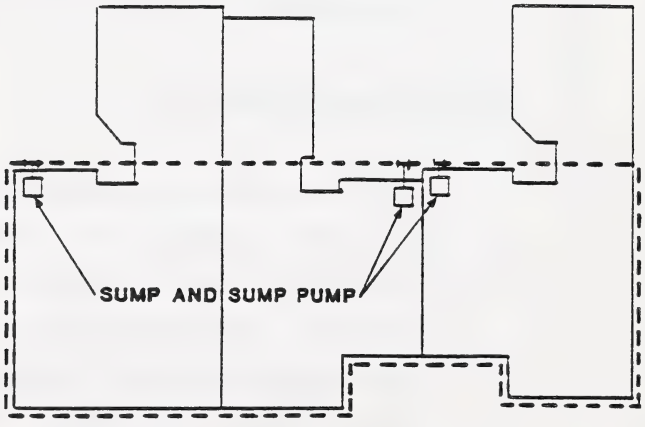
Two developers were interviewed about block townhouse developments. Both developers had ongoing communications with the property owners within the developments. The developers were aware of sump pump system problems, particularly discharge water, and tried to mitigate the inconveniences with landscape changes. The problem of roadway and sidewalk icing is a result of site drainage design that includes landscaped swales, inverted crown roadways, and storm sewer catchbasins in the centre of roadways. The developers stated that it is difficult to correct icing problems without reconstructing significant portions of the drainage system. The developers have regraded and redirected sump and roof discharges to mitigate problems at several similar developments in Edmonton, with limited success.

4.1.2.2 Mechanical contractors

Two mechanical contractors were contacted regarding multi-family site sump pump system installation practices. They stated that the codes do not regulate sump pump system installation. They also indicated that there are two common industry alternatives for these installations. One alternate is to construct one sump and pump for every 120 m (400 ft) of foundation drain tile. The location of the sumps is usually decided onsite by the contractor. The other alternative is to construct a sump and a pump for each individual unit. Figure 6 illustrates the two alternative arrangements.



Sump pump system layout with one sump pump for every 120 m (400 lin. ft) of drain tile.



Sump pump system layout with one sump pump per unit.

Figure 6 MULTI-FAMILY SITE
SUMP PUMP SYSTEMS
ALTERNATIVE LAYOUTS

4.1.2.3 Plumbing inspectors

The municipal and provincial plumbing inspectors interviewed confirmed that codes do not regulate sump pump systems. Therefore, it is the understanding that the inspectors may make recommendations to contractors but cannot impose a specific installation standard to be followed. Municipal inspectors do enforce the bylaws requiring that foundation drain water not be discharged to sanitary or combined sewers.

The general observation of the municipal inspectors is that sump pump systems, that are properly designed and installed, work well. One inspector suggested that in cases of high groundwater situations, connection of the foundation drain to a storm sewer system would provide better service.

4.1.2.5 Lawyers

Based on the telephone conversations with two City of Edmonton legal staff, the concerns are:

1. For multi-family sites the ownership of the foundation drain system is not defined.
2. The sump pump system that transfers drainage from several different units is located in one unit. The sump pump operation and maintenance and all the related costs are commonly the responsibility of the owner of the unit with the sump pump.
3. In the event of sump pump system failure, it is not known which party is responsible and liable for possible damages.

According to those interviewed, these issues have not arisen in the courts; consequently, there is no legal precedent.

4.2 Manufacturing and Supply Sectors

Several pump supply companies located in Edmonton were contacted. Two manufacturers supply most of the sump pumps to the local housing industry; Little Giant, of Oklahoma City, Oklahoma and Hydromatic Pumps, of Ashland, Ohio. Two local pump suppliers and one pump manufacturer responded to mailed questionnaires and their replies are summarized below. Refer to Appendix A, page A-7 for additional information.

- The most common sump pumps installed are the Little Giant models 5ASP and 6CIA.
- Upright column sump pumps were not recommended for use because they are too tall for many installations and not reliable.

- The Little Giant Pump Company stated that the automatic switch is the most commonly replaced part.

4.3 Contractors

Initially five weeping tile/foundation contractors were contacted in the Edmonton area, but only one firm responded. Later, two mechanical contractors recommended by developers and inspectors were interviewed.

The two contractors indicated that sump pump systems can be designed to convey groundwater with reliability, but since no system minimum standards are specified, and since installation is highly competitive, the least expensive system is usually installed.

4.4 Real Estate

Because several homeowners had negative opinions of sump pump systems and many more had bypasses to the sanitary sewer installed for winter sump pump discharge, it was thought that the saleability of houses with sump pumps may be affected. To determine the effect of sump pump systems on the saleability of homes, eight real estate firms were mailed questionnaires. The real estate firms were randomly selected from the Edmonton and Calgary areas. Two real estate services responded and stated that the presence of a sump pump system did not affect the saleability of homes.

4.5 Municipal and Provincial Authorities

The building and plumbing inspectors of the City of Edmonton, Strathcona County and Provincial Plumbing and Gas, Alberta Labour, were contacted at their offices to discuss sump pump systems. Recurring comments were the

absence of standards or guidelines for sump pump systems and the question of jurisdiction. The inspectors said they often make recommendations to the homeowners/builders during construction. Common recommendations are:

1. Provide a backup system for cases of power and/or pump failure. The backup systems suggested were a sump pit high-level bypass to the sanitary sewer and/or a standby 12-volt operated pump.
2. Where possible, connect foundation drains to storm sewers.
3. Purchase a high quality pump.
4. Plan the sump pump discharge location based on lot drainage and planned landscaping.

The inspectors stated that, if they were given the opportunity to discuss the sump pump system with the builder or homeowner while the home was under construction, often their recommendations and suggestions were often acted upon.

4.6 Site Inspection and Field Tests

Within the data-gathering stage several sump pump systems were inspected and pump performance tests were conducted on two systems. The detailed site reports are included in Appendix A. Based on the site investigations, the average sump pump system may be summarized as follows:

System features

1. Sump pit capacity 600 x 600 x 600 mm
2. Treated plywood sump liner
3. Gravel/dirt bottom
4. Influent pipe 100 mm ABS
5. Discharge pipe 38 mm ABS
6. Concrete splash pad at discharge

System discharge

The majority of discharge locations are to the front of the residence onto landscaped areas. The discharge locations for the multi-family sites were varied, including:

1. Grassed areas
2. Splash pads
3. Concrete driveways
4. Concrete patios (back yards)
5. Concrete swales

System performance

Sump pump performance was tested at two locations. Both locations were equipped with the Hydromatic Pump Model SW25/33A. The calculated discharges are presented on Figure 7. Based on the two sump pump performance tests, the pumps operate very favourably when compared to the design performance curves. In both cases the systems performed slightly better than the design pump curves.

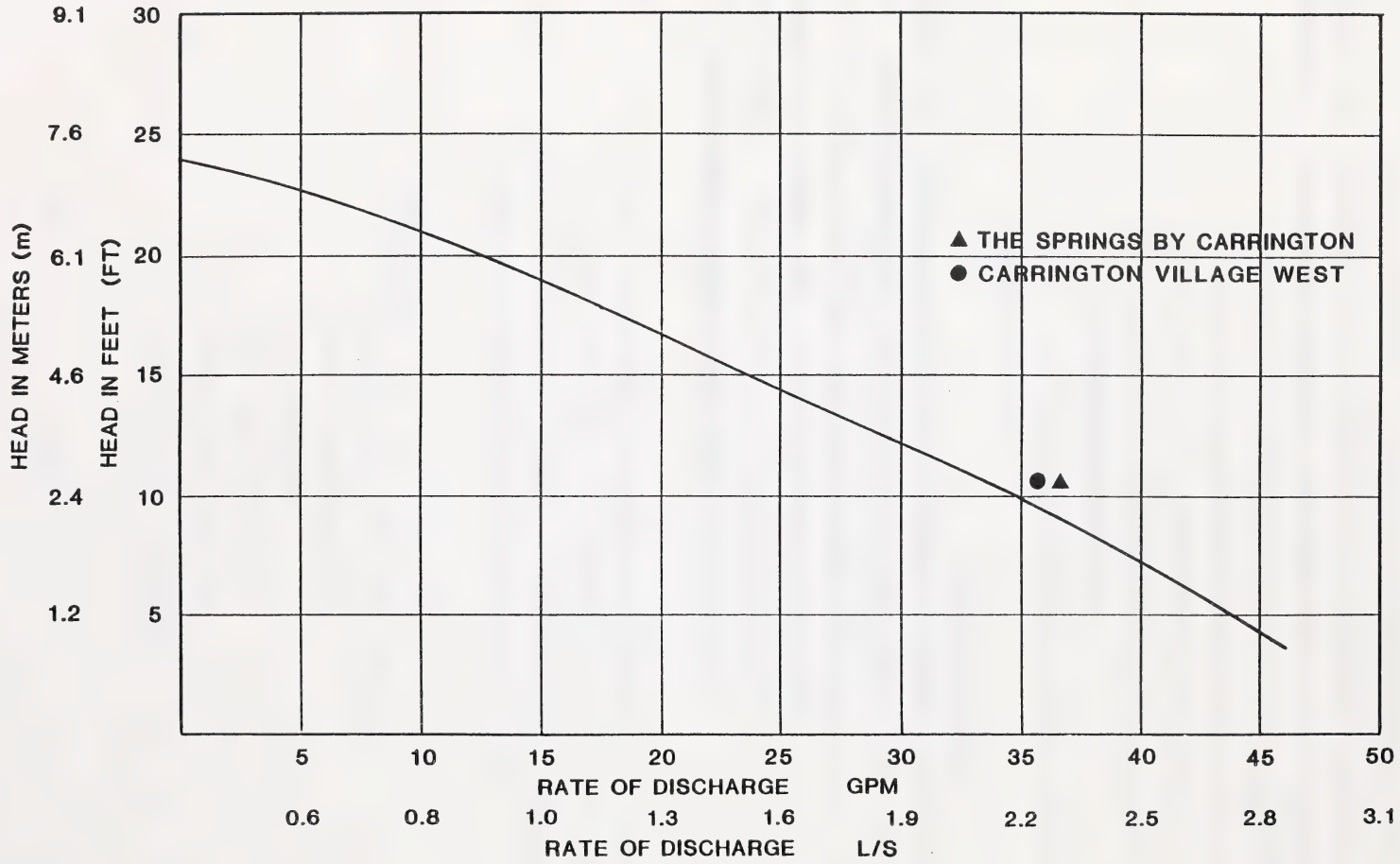


Figure 7 HYDROMATIC PUMP CURVE
MODEL SW25/33A

5.0 ANALYSIS OF INFORMATION SURVEY AND PROBLEM IDENTIFICATION

In analyzing the information obtained and the sources of the information, some facts appear to be significant:

- For single-family residences in neighborhoods where sump pump systems are mandatory, a minority of the systems are considered active (systems that convey foundation drainage on a regular basis).
- Of those that are active, the majority are perceived as systems that pose a problem to the resident because of difficulties with discharge water and power/pump reliability.

The predominant problems identified in this study are summarized below. The first two items were the main concerns of homeowners and the remaining two were the prevalent comments of the contractors, inspectors, and the legal sector.

- The effects of the discharge of sump water to sidewalks, roadways, and lawns
- Potential power and/or pump failure
- The lack of standards and guidelines for sump pump system design and installations
- The lack of definition of the liabilities and responsibilities of sump pump systems for multiple-unit housing

These four items are discussed further in the following sections.

5.1 The Discharge of Sump Water

The Milwaukee Study (4) evaluated sump pump discharges. The following quote summarizes the findings and the comment holds true for this study.

- *The discharge of sump pumps to yard surfaces at the study sites created no wet basement walls or sidewalk or street icing problems when the yard was sloped to prevent ponding near the house (within 10 feet), and when the yard area was large enough (50 feet minimum*

lot width) to permit the water to percolate into the soil. This finding was observed at 15 of the study sites where the recorded I/I rates were generally less than the average rate for all of the study sites. Therefore, the sump pumps were not extremely active. Based on observed conditions at several non-study sites, it is concluded that the discharge of sump pumps to yard surfaces in historically wet areas of the MMSD could result in sidewalk/street icing conditions.

The homeowner comments, questionnaire information, and site investigations of this study support the Milwaukee findings. When sites have active sump pump systems discharge, water does cause site inconveniences. The ideal objective is to eliminate inconveniences caused by the discharge.

Some proposed methods to reduce the negative impacts of sump pump system discharges have been developed and are listed below:

1. Connect discharge piping to the storm sewer system. This would eliminate surface discharge of groundwater but would require a backwater valve and a storm sewer main of sufficient depth in all areas.
2. Design the discharge location of sump pump systems by correlating volume of discharge waters to site infiltration rates. By correlating discharge volumes to infiltration rates, the discharge location and landscaped area would be specified similarly to the requirements established for sanitary sewage disposal field. For new homes and extensively renovated homes, the landscaping of the sump discharge location could be carried out during the normal lot grading and landscaping and accordingly there would be minimal to no cost.
3. Design surface drainage to minimize icing and ponding. For example, in multi-family site developments steeper slopes and a crowned roadway cross section could be used rather than an inverted crown

design. This would limit the icing to the gutter areas at the sides of the road.

4. Provide onsite stormwater management of sump water such as onsite detention basins. The design of these systems would be based on site infiltration and sump system discharge rates.

5.2 Power and/or Pump Failure

The sump pump is an electromechanical device that is, unfortunately, not fail proof. A sump pump system will fail to operate in times of power outages or when breakdowns such as malfunctions of the motor, pump, or controls occur.

The survey found that the fear of power and/or pump failure is a major concern, especially for homeowners who have experienced basement flooding previously. One individual experienced such a flooding and, as a result, personally monitors the sump pump during storms, even if he must miss work to do so. Another respondent refrains from taking vacations because of the concern over basement flooding. It is impractical to design a fail-safe sump pump system; however, the systems should provide an acceptable service level and confidence.

In order to mitigate the problems associated with pump failure or power outages, two options are proposed:

1. Size the sump to provide extra storage capacity and cycle time as a measure of protection from power or pump failure. Edmonton Power indicated that the maximum duration of power outage resulting from a storm is typically 2 hours. The report "Field Evaluation of Foundation Drain Response" (5) suggests the flowrates for clay soils are from 0.12 L/s to 0.19 L/s. A sump storage capacity of approximately 1 m^3 would be adequate to accommodate the volume of

inflow during a 2-hour power outage.

2. Provide a standby battery-operated sump pump for protection against power outages and pump failure. There are a limited number of battery-operated units available in the current market place. A standby battery-operated model manufactured by Simer Pumps was investigated and tested.

5.3 Requirements, Standards, and Guidelines

All of the sectors interviewed in the study indicated that the lack of standards and guidelines regarding sump pump systems causes confusion. It is not conceivable for homeowners to be responsible for improved system design and operation because they cannot be expected to understand all the required considerations sufficiently, and are not usually involved in the construction-phase of sump pump systems.

Because competitive pricing is a reality, the least expensive system that meets the regulations will most likely be installed by builders. Therefore, standards and construction regulations must define the minimal allowed system which meets functional requirements.

Local governments can enact building standards that complement or exceed the codes; therefore, the issue of minimum requirements may be addressed based on the results of future system testing.

5.4 Multi-family Legal Responsibilities

The legal issues of multi-family site developments with common drainage/sump pump systems are beyond the scope of this report; however, the problem has been identified and warrants investigation.

6.0 TESTING PROGRAM

Sump pump systems are a component of the overall drainage plan developed by a community. The purpose of sump pump systems is to eliminate foundation drain flows from municipal sanitary sewer systems and by so doing minimize the possibility of sewer backup and basement flooding. One of the objectives of the Sump Pump Study is to investigate the performance and effectiveness of sump pump systems. This testing program sought to optimize the systems by testing design modification and operational improvements. The field testing did not examine alternative methods of foundation drain discharge that were conceptually different (i.e., a third-line system used by some municipalities.)

Appendix B presents the results of controlled field testing. Additional observations regarding system performance are presented in Section 7.0.

6.1 Objectives of the Field Testing Program

The objectives of the field testing program were to replicate identified problems and then modify the sump pump system to implement proposed improvements. Section 5.0 of this report identified four predominant problems of sump pump systems:

- The discharge of sump water
- Potential power and/or pump failure
- The lack of standards and guidelines
- The lack of definition of liabilities and responsibilities of sump pump systems for multi-unit housing

The field testing program focused on resolving problems related to sump water discharge and power and/or pump failure.

In order not to defeat the original objectives of sump pump systems, the

following parameters were established for the proposed system modifications and field testing:

1. Modification to the sump pump system would not transfer the problem from one system to another; for example, the direct transfer of foundation drain flow from the sanitary system to the storm or roadway system,
2. The modifications to the system would not increase foundation drain flow; if possible, foundation drain flow would be decreased.

A series of field tests were conducted at the Strathcona Research Facility to determine the effectiveness of the sump pump system modifications. The field tests addressed:

1. Onsite sump water discharge alternatives. The discharge alternatives tested were:
   a) surface discharge on landscaped areas
   b) surface discharge to a typical splash pad
   c) discharge to conduit and off site disposal
   d) surface discharge to the backfill zone
2. Various sump sizes for storage capacity during pump/power failure.
3. Battery-operated, direct current (dc) sump pumps as backups in case of power failure.

6.2 Test Site Description

Sump pump systems and system modifications were field tested at the Lot Drainage Research Facility in Strathcona County. The foundation drainage system at the facility was specifically designed for foundation drain research.

Figures 8 through 16 illustrate the site configuration and monitoring details. The following descriptions provide additional information for each figure:

Figure 8: Lot Drainage Research Facility

The lot provides back to front drainage, which is the predominant lot drainage pattern in newer subdivisions. With the valving of the foundation drain and the geomembrane, the foundation drain response of the back yard may be separated from the front yard. The simulated rainfall events applied water uniformly over the site, including the roof area.

Figure 9: Piezometer Locations

The piezometers were installed to monitor groundwater fluctuations within the backfill zone and the undisturbed soil. Front, back, and side yards are monitored.

Figure 10: Foundation Drain and Sump Plan

The site may be split to measure back-yard and front-yard foundation drain flow separately. The back-yard foundation drain flow may be directed to Sump 1 and the front-yard flow to Sump 2. Either sump may be used if the test is for a single sump pump system configuration.

Two sump volumes were tested:

Sump 1 was designated the large sump and has the following dimensions:

Area 0.980 x 0.976 = 0.957 m^2

Total depth (top of floor to base) ≈ 1.0 m

Total volume = 0.96 m^3

Active volume (base to invert of inflow) = 0.42 m^3

Sump 2 was designated the small sump and the volume was adjusted by fitting rigid insulation to the sump walls. The dimensions of Sump 2 used during the field testing were:

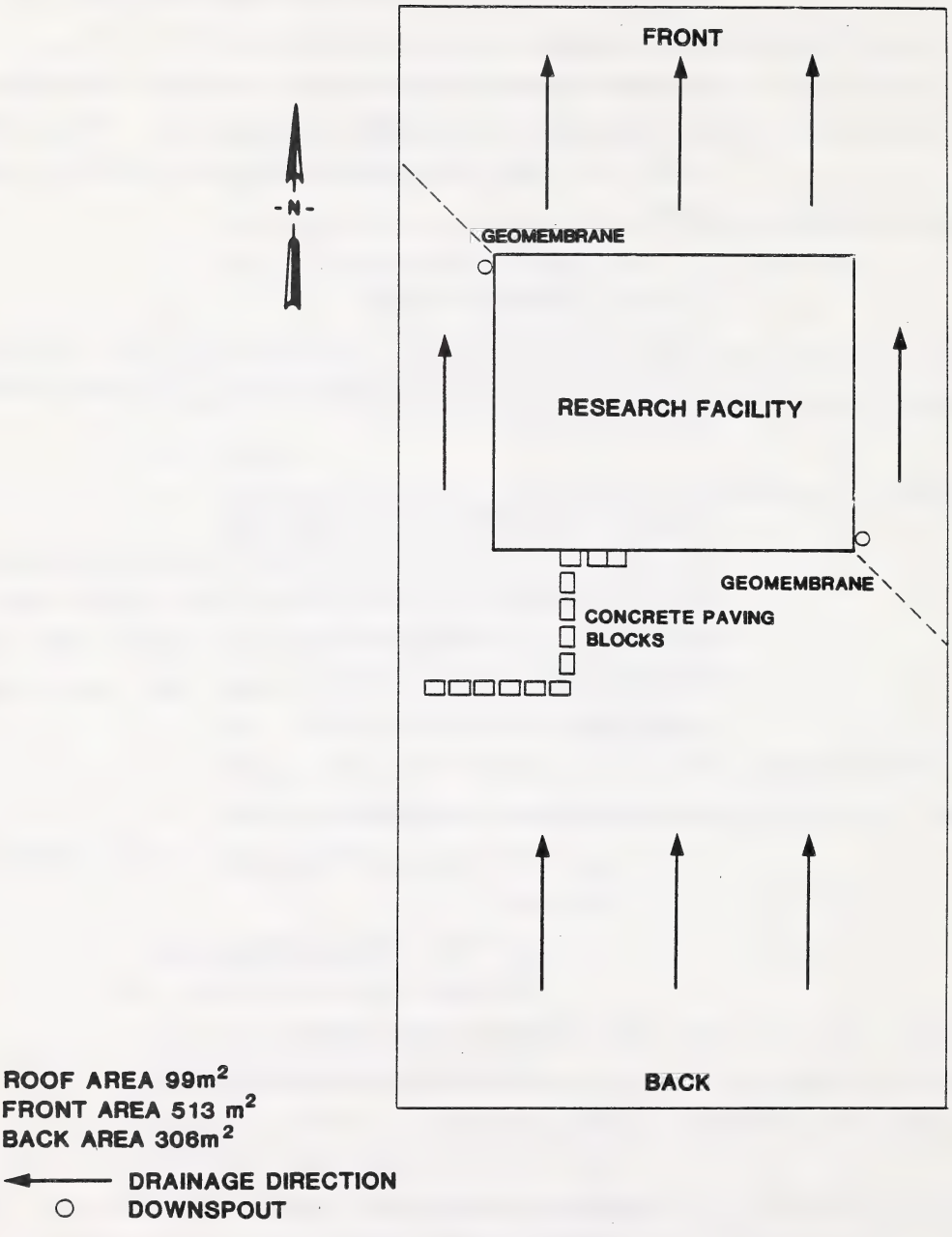


Figure 8 LOT DRAINAGE
RESEARCH FACILITY
LOT PLAN

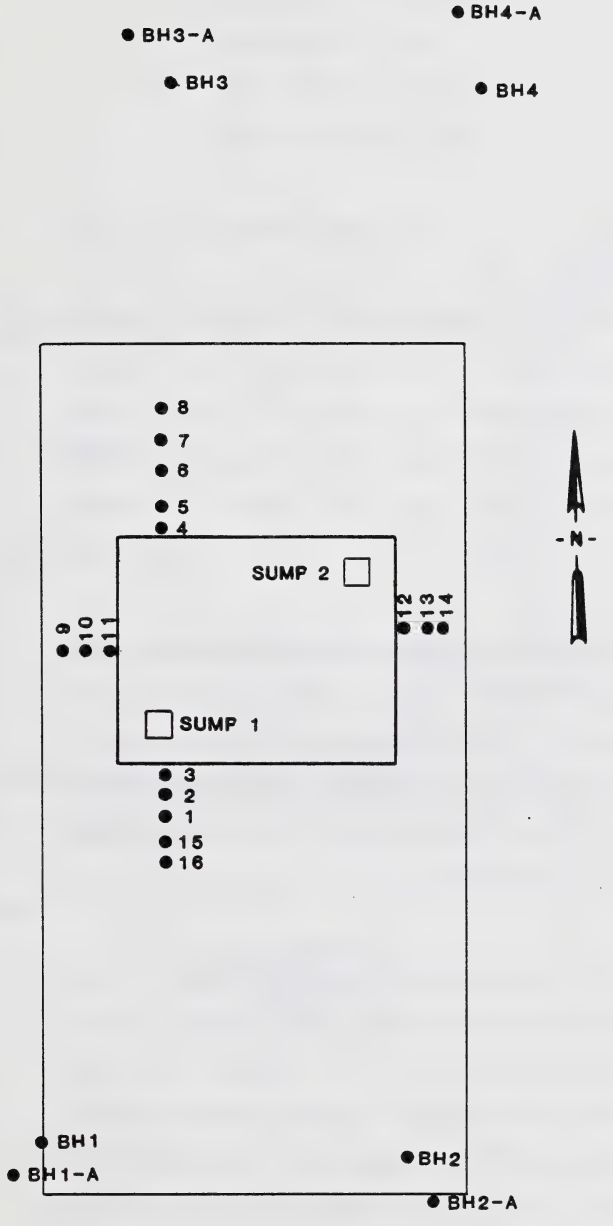


Figure 9 PIEZOMETER LOCATIONS

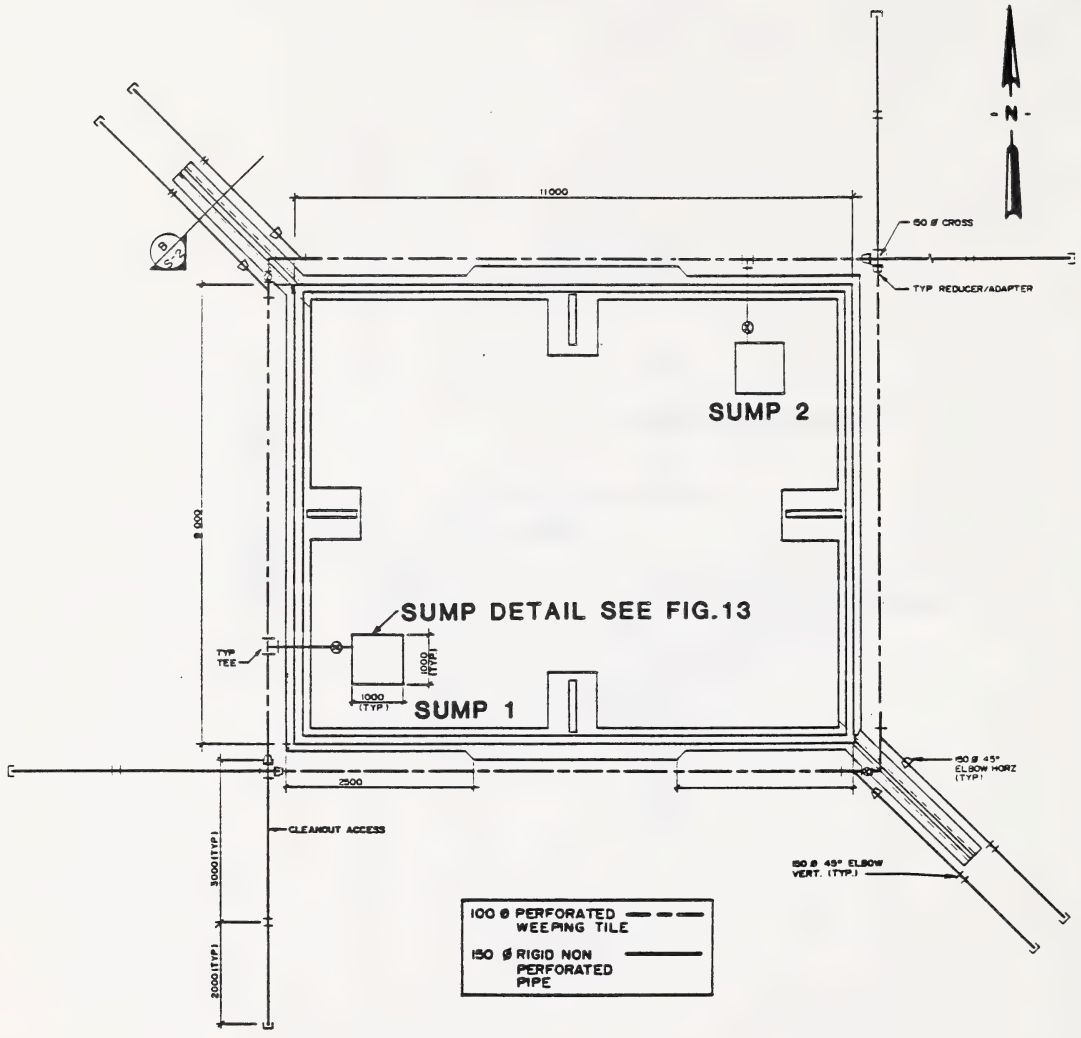


Figure 10 FOUNDATION DRAIN AND SUMP PLAN

Area .670 x .976 = 0.486 m^2

Total depth ≈ 1.0 m

Total volume = 0.96 m^3

Active volume 0.21 m^3

Figure 11: Piezometer As-Built

The piezometers were installed to monitor groundwater fluctuations. As shown on Figure 9, a total of 24 piezometers are installed. Figure 11 details the three piezometers on the back-yard portion of the site, which is typical for all four sites. Piezometers 3, 2, and 1 monitor groundwater fluctuations immediately over the foundation drain, at the transition of backfill and native soil and within native soil, respectively.

Figure 12: Foundation Drain and Sump Pump Detail

The foundation drain flows into the sump (for both Sump 1 and 2) and discharges to surface by automatic pump. The sump water elevation is monitored by a level recorder, thus recording inflow. The pump is monitored by an on/off sensor that records running time, which allows for discharge calculations, total pump running time, and cycle time.

Figure 13: Schematic of Site Instrumentation

The site of the research facility has instrumentation that automatically records data 24 hours a day. Natural rainfall events are measured by a Rimco raingauge, which is a tipping bucket type. The number of tips is recorded by the data logger that is downloaded into a computer and analyzed using the manufacturer's software. The Rimco raingauge records were checked on a weekly basis by calibrating to a standard raingauge onsite. The raingauge records allowed for natural rainfall to be separated from simulations when the events overlapped.

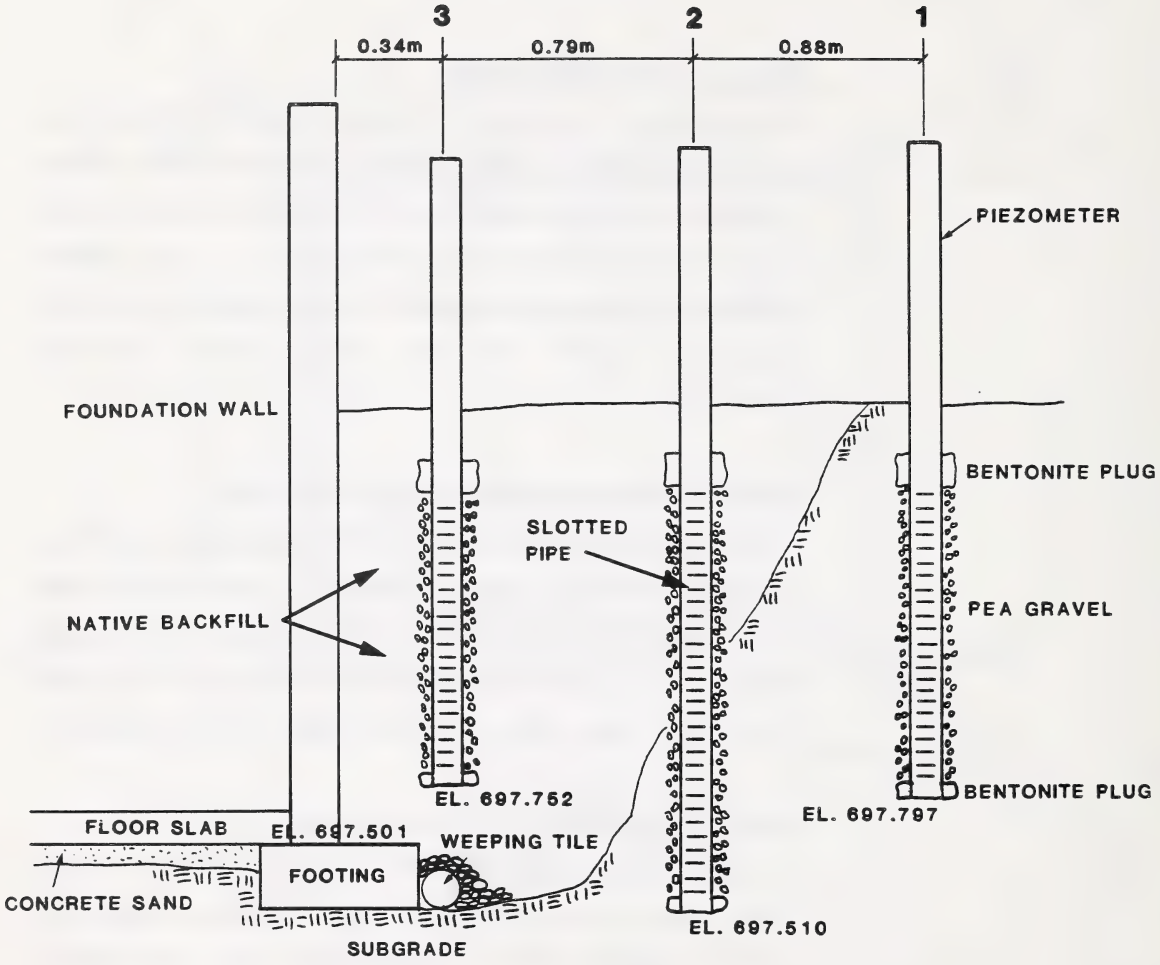


Figure 11 PIEZOMETER AS-BUILT FOR BACK YARD - FRONT YARD PIEZOMETER INSTALLATION IS THE REVERSE

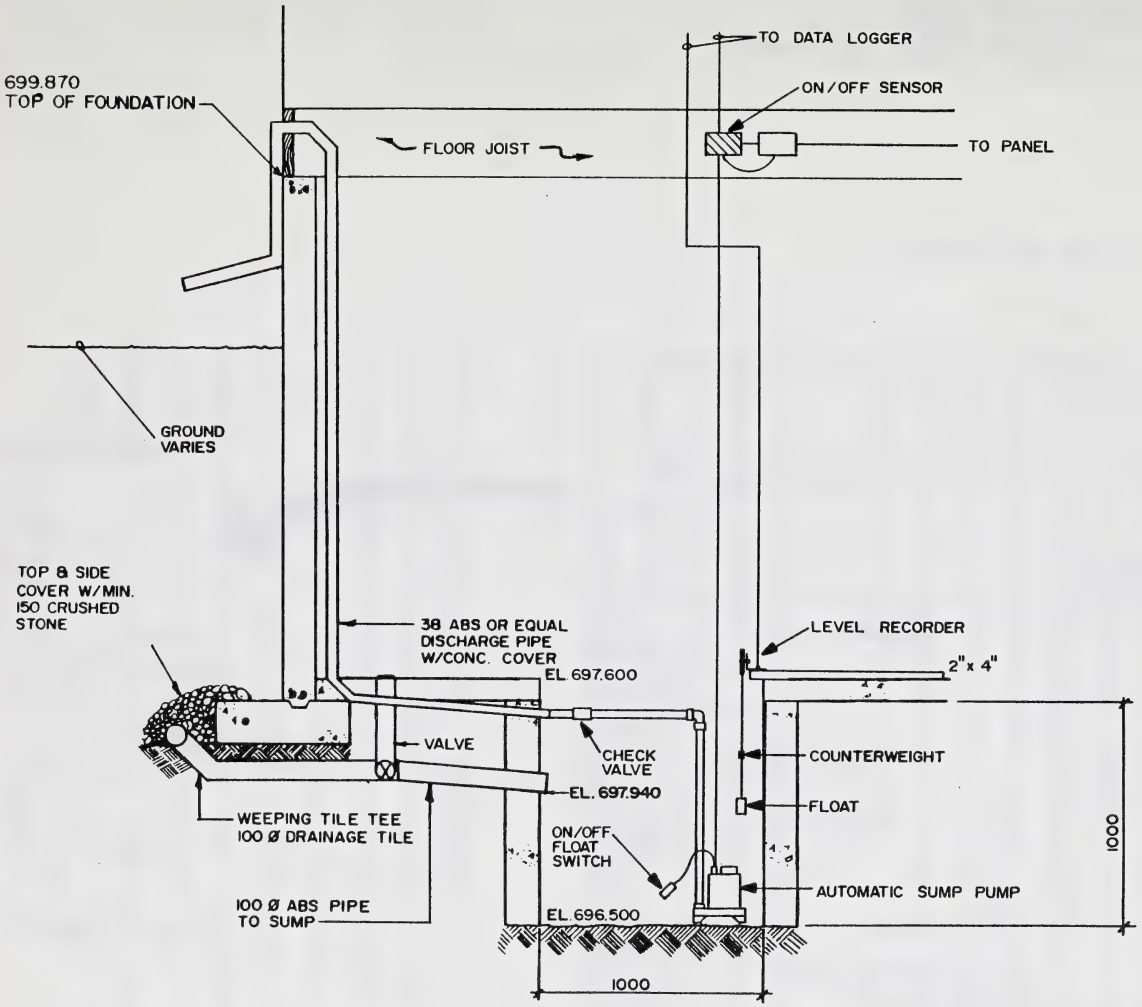


Figure 12 FOUNDATION DRAIN AND SUMP DETAIL

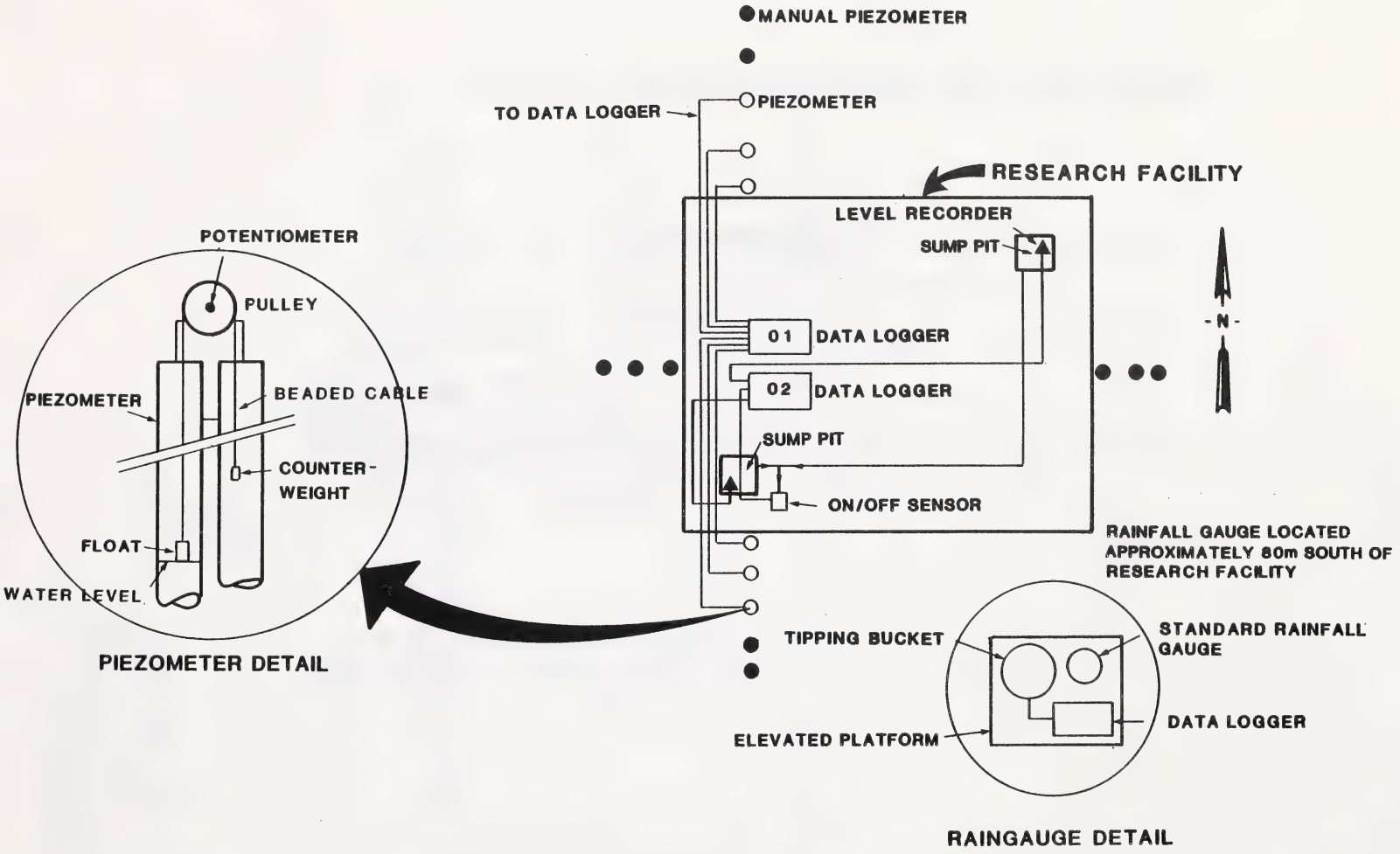


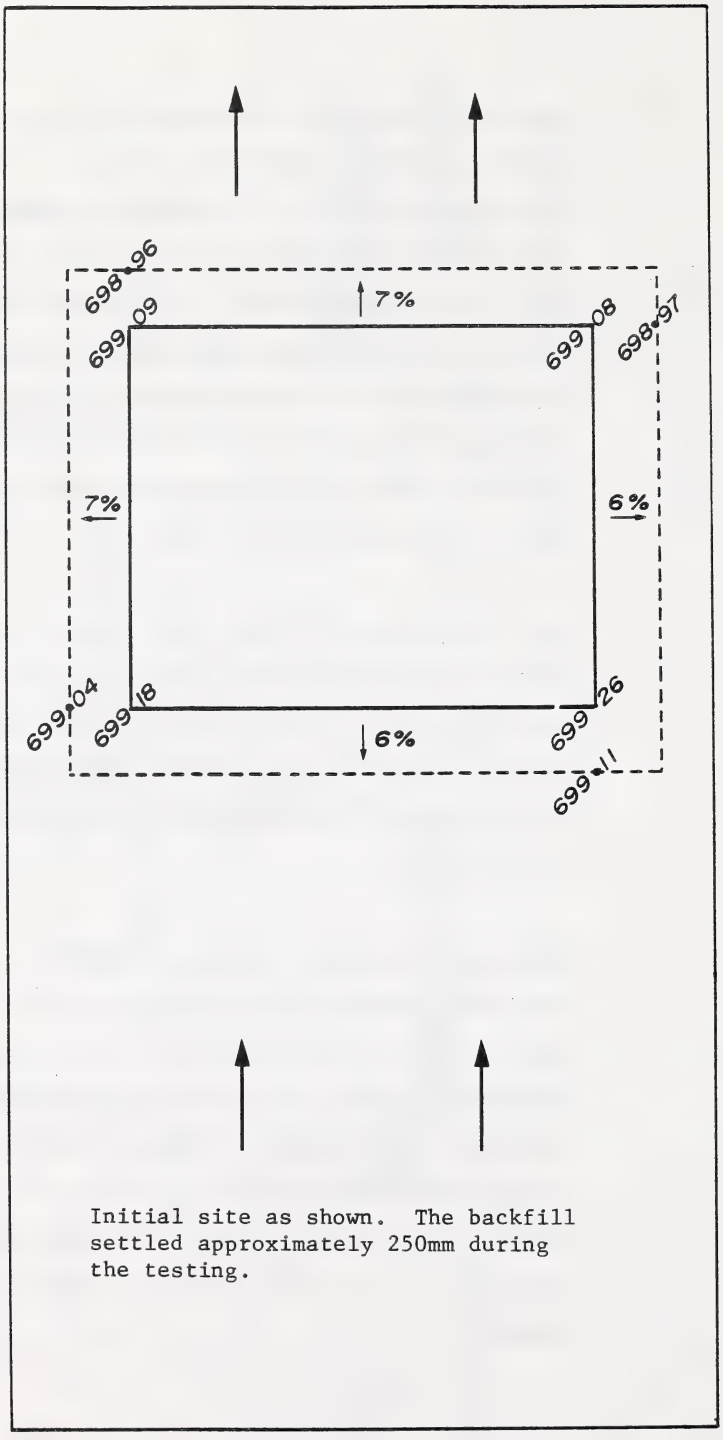
Figure 13 SCHEMATIC
SITE INSTRUMENTATION

Groundwater fluctuations were measured by 16 piezometers grouped at various distances around the foundation. Three piezometers monitoring the backfill zone in the back yard, and three similarly in the front yard, were furnished with float and counterweight assemblies. The float elevations generated potentiometer readings that were recorded on Data Logger 01. Data Logger 01 recorded readings at 4-min intervals for the six piezometers equipped with the device. The remaining 10 piezometers around the foundation, two at each lot corner, were read manually at the start of each test, 2-hour intervals during the test, and at the end of each test.

The sump water level in each sump was monitored by float and counterweight devices connected to Data Logger 02. The sump pump was equipped with on/off sensors that were also connected to Data Logger 02. The water level in the sumps was recorded every 4 min and also at pump start and stop. The pump running time was recorded to 1-sec accuracy.

Figure 14: Lot Grading - Uncompacted Backfill

This figure illustrates initial backfill zone grading prior to rainfall simulations. During the testing program on uncompacted backfill the material settled approximately 250 mm at the foundation wall. For this study, uncompacted backfill is defined by the following construction practice: material end dumped to full depth with minimal surface levelling effort by heavy equipment. The tests of August 26, 28, and September 3, 5, 6, and 7, 1991 were conducted on uncompacted backfill.



Initial site as shown. The backfill settled approximately 250mm during the testing.

Figure 14 LOT GRADING UNCOMPACTED BACKFILL

Figure 15: Lot Grading - Compacted Backfill

Lot grading for the test simulations of July 15, and 16, 1991 (provided for comparison) were conducted on compacted backfill. For this study compacted backfill was defined by the following method of placement:

- Material was end dumped to an uncompacted depth of approximately 1.5 m
- Backfill material was bucket tamped by a back hoe
- Placing additional material to bring backfill to grade
- The final lift was plate tamped by hydraulic hoe tamper

Figure 16: Pump Curve - Goulds Model 3871

The field tests where foundation drain response was the indicator of effectiveness used the Goulds Model 3871 pump. A single pump model was selected for these tests to limit the variables in foundation drain flow analysis.

6.3 Test Procedures

The testing component of the Sump Pump Study was carried out in the following time periods:

- During the spring and summer 1991 a concurrent research project, Lot Drainage Characteristics, Project 1 - Clay Till Soil was carried out at the research facility. In excess of 10 natural storm events and 50 simulated rainfall events were monitored. Observations were made during the site set-up in May 1991 and the data was collected during the program to complement this study.
- A series of four simulations of modifications to the sump pump systems were done in September 1991.

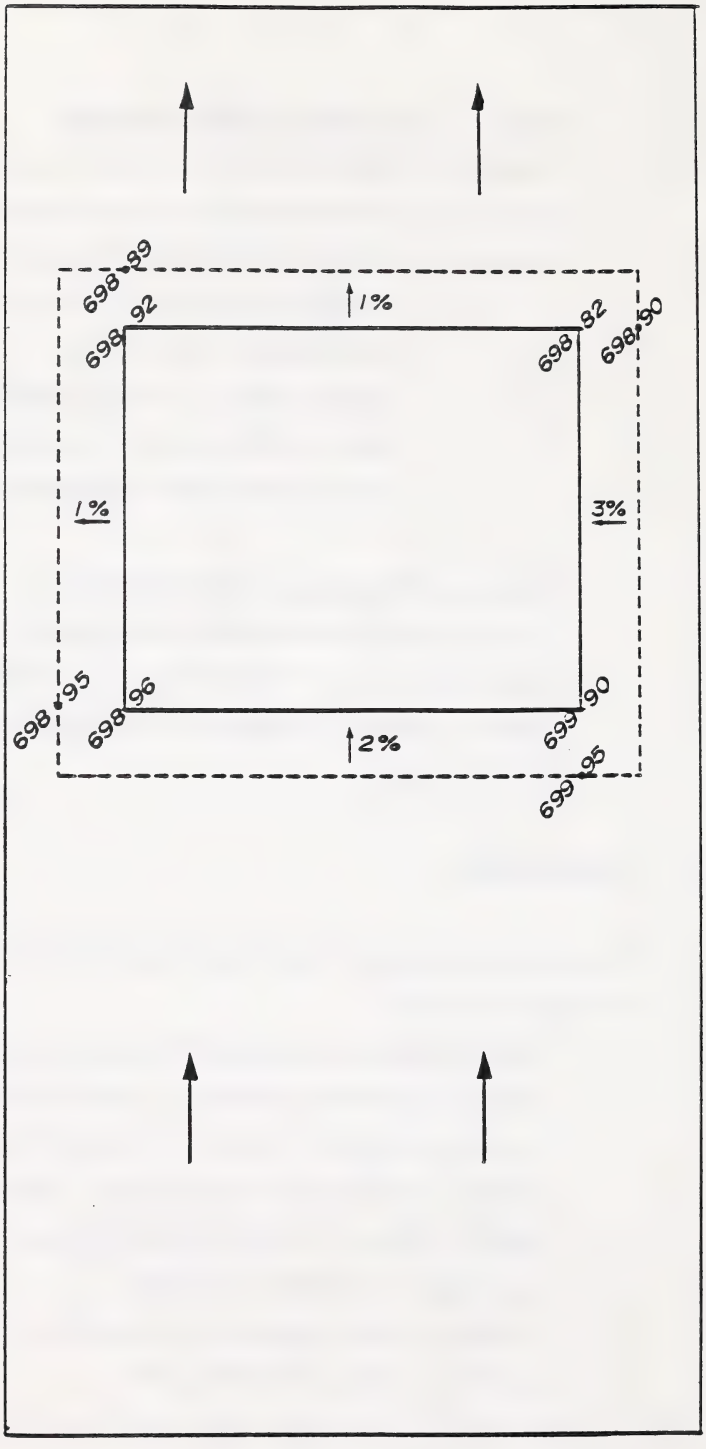


Figure 15 LOT GRADING
COMPACTED BACKFILL

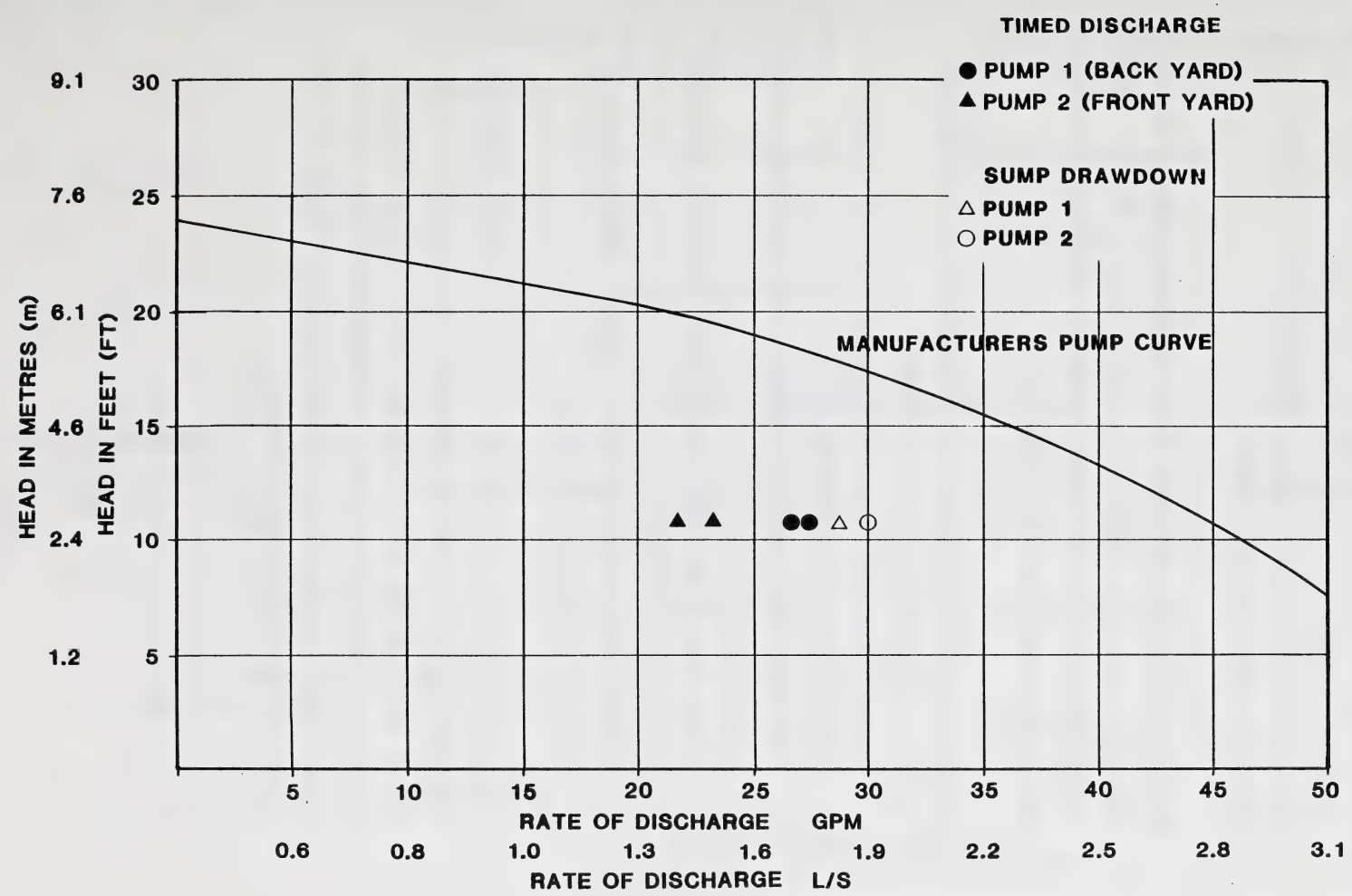


Figure 16 GOULDS PUMP CURVE
MODEL 3871

The testing of possible solutions for potential power and/or pump failure, presented in Section 5.2, was conducted concurrently in September 1991 with the sump discharge alternative testing. Possible solutions considered were larger sump sizes and a standby pump.

During the field testing, the research facility was equipped with two Goulds Model 3871 pumps with on/off current sensors as shown on Figure 13. The pump discharge rates averaged 1.9 L/s. Additional information regarding the sump pumps tested is presented in Section 7.3.2.

Individual tests of the four simulations of modification to the sump pump system were conducted and monitored as follows:

- Rainfall events were simulated by applying water with soaker hoses and oscillating sprinklers (Figure 17).
- Piezometers were monitored to determine water table changes during testing (Figure 9).
- Water levels in the sumps were monitored to determine foundation drain flowrates (Figure 12).
- On/off current sensors on the sump pumps (Figures 12 and 13) recorded sump pump running time.

At the start of each test the water level in the piezometers was read and the foundation drain base flowrate was determined. The site was then configured for the given test and rainfall simulations carried out (see hyetographs Appendix B). Piezometer and pump on/off readings were stored on the data loggers, which were downloaded the following day. The data was then translated using the manufacturer's software.

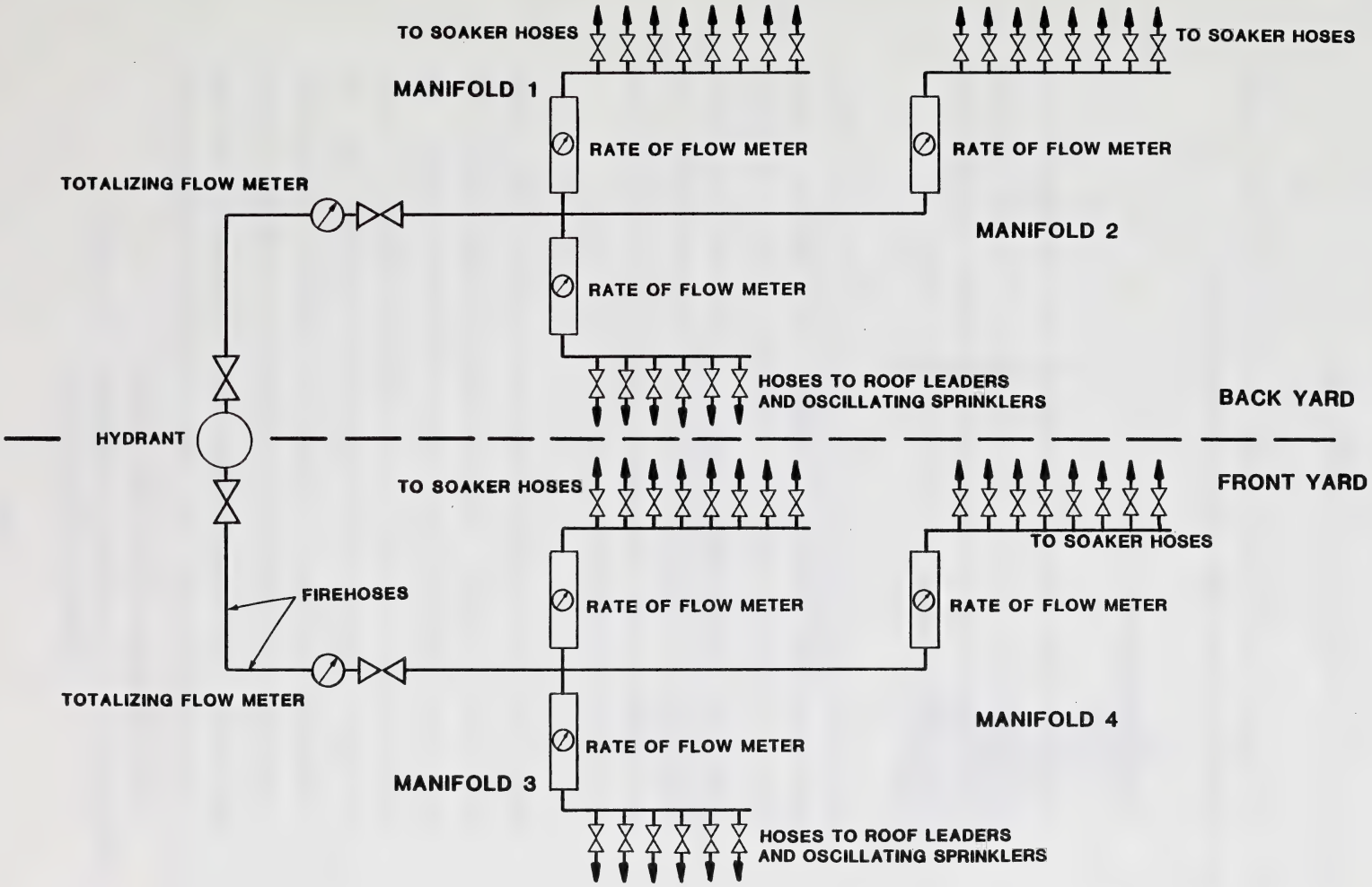


Figure 17 RAINFALL MANIFOLD

7.0 TESTING PROGRAM RESULTS AND ANALYSIS

The following sections describe both the general observations and results of sump pump system testing from October 1990 to mid-September 1991.

7.1 General Observations at the Test Site

Several general observations of the sump pump system at the research facility are noted below and presented in chronological order. The observations listed are random events during the program that have assisted in the analysis and in formulation of recommendations for sump pump systems.

April 25, 1991 The research facility was completed on December 7, 1990, and the sump pumps were installed on April 25, 1991. Over the winter and spring the foundation drain water had filled both sumps to capacity (approximately 2 m^3); however, the basement did not flood. The backfill was uncompacted and had settled approximately 300 mm over the winter. The Simer pump was used to drain the sumps and later Goulds Model 3871 pumps were installed as the standard test pumps.

May 14, 1991 The sump pump failed during an average intensity rainfall event, Figures 18 and 19. The failure resulted in a flooded basement. The time of pump failure was unknown and was discovered on May 15. Site grading at the time was poor with noticeable backfill settlement around the foundation. Also, the sump discharge was at the foundation wall. It is estimated that there was 7 m^3 of water in the basement. The sump pump system failure was attributed to a drain rock, from the sump base, caught in the impeller. Pump failure caused by a rock in the impeller, occurred again on both September 6 and 7, 1991. These pump failures occurred during the field testing program for sump pump systems.

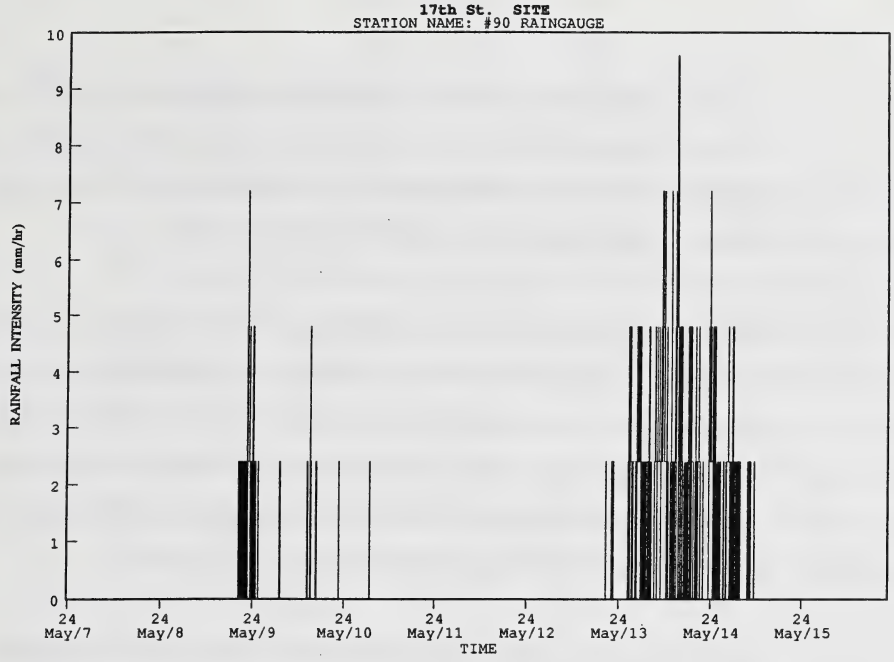


Figure 18 RAINFALL INTENSITY

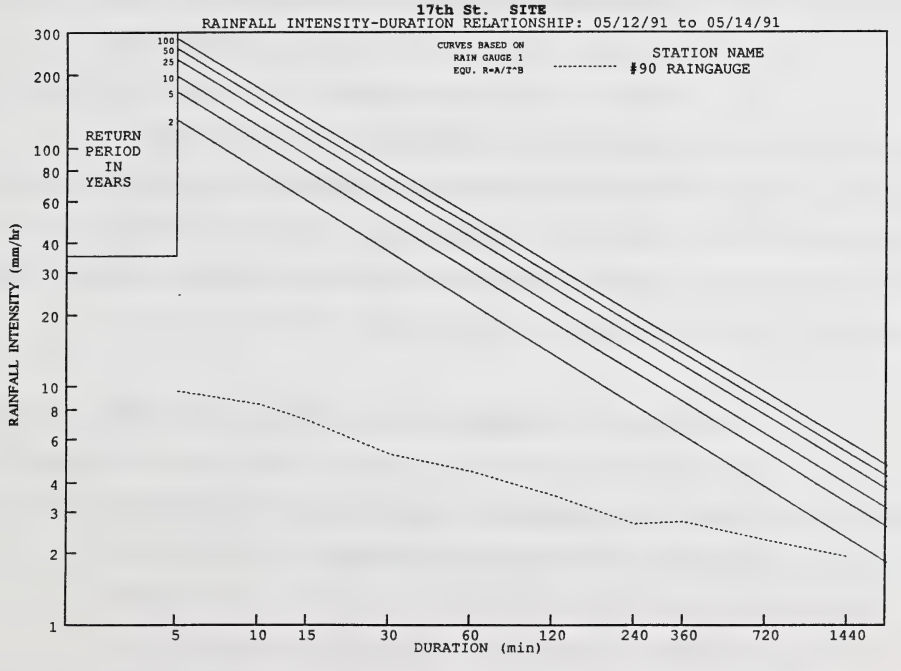


Figure 19 RAINFALL INTENSITY, DURATION, FREQUENCY CURVE

A local landscaping contractor, who was assisting with backfill landscape changes, suggested that the sump pump be placed in a slotted plastic container to solve both the rock problem and other maintenance needs of the sump system. This suggestion is presented in Section 8.0.

May 20, 1991 Sump water was discharged at the foundation wall from April 25 to May 20, 1991. The discharge water caused saturated ground conditions. Site personnel would sink 5 to 10 cm into the ground when walking through the sump discharge locations. When the sump water was discharged on the lawn, grass cutting was difficult. The mower wheels rutted the lawn and the mower body would drag through the discharge location.

Following are general observations made throughout the summer regarding sump pump systems:

- An active system results in the constant sound of dripping water.
- Due to the requirements of installation, maintenance of the pumps at the bottom of the sump is inconvenient and difficult.
- Similar to roof leader extensions, sump splash pads and the discharge pipe extensions interfere with yard maintenance.
- Throughout the spring and summer the two pumps discharged in excess of 150 m^3 of foundation drain water and discharge areas were always saturated. This volume of water is for the test site only and cannot be compared to an actual home.

Throughout the testing program the sump pump systems adequately performed the function of conveying foundation drain water to the ground surfaces. Pump failures occurred on September 6 and 7 under extreme inflow conditions attributed to the lot grading condition.

7.2 Testing Program Results

The effectiveness of the sump pump system modifications was evaluated on the basis of how the modified systems resolved the two identified concerns: the discharge of sump water and the possibility of basement flooding caused by power and/or pump failure during a storm event. The purpose of sump pump systems is to convey foundation drain water to the lot surface; therefore, a properly designed system should not increase drain tile flowrates (ie. sump discharge water recirculating to drain). Based on these facts, foundation drain flow, pumping time (pump cycle time), and the volume of water in the sumps and conveyed by the system were the measured indicators of sump pump system effectiveness.

The testing program graphs and data for the simulations are discussed below and the test results presented in detail in Appendix B. The monitored data provided comprehensive records for the analysis of sump pump system performance.

For each of the sump pump system performance simulation tests carried out, the following information was compiled: an inflow hydrograph, a hydrograph of recycled sump water, and the pump recycle time. The test of September 3, shown in Figures 20a, 20b, 20c, and 20d is typical for the testing program and the figures and data are described below to assist in the review of the results.

Figure 20a: Foundation Drain Response

The response hydrographs show the rainfall induced inflow to the foundation drain in relation to the time of the storm event. The hydrographs have two vertical scales. The main scale shows rate of inflow in litres per second. The one in italics shows the precipitation intensity in millimetres per hour. The inflow rate is plotted as a line on the graph; precipitation is shown as a

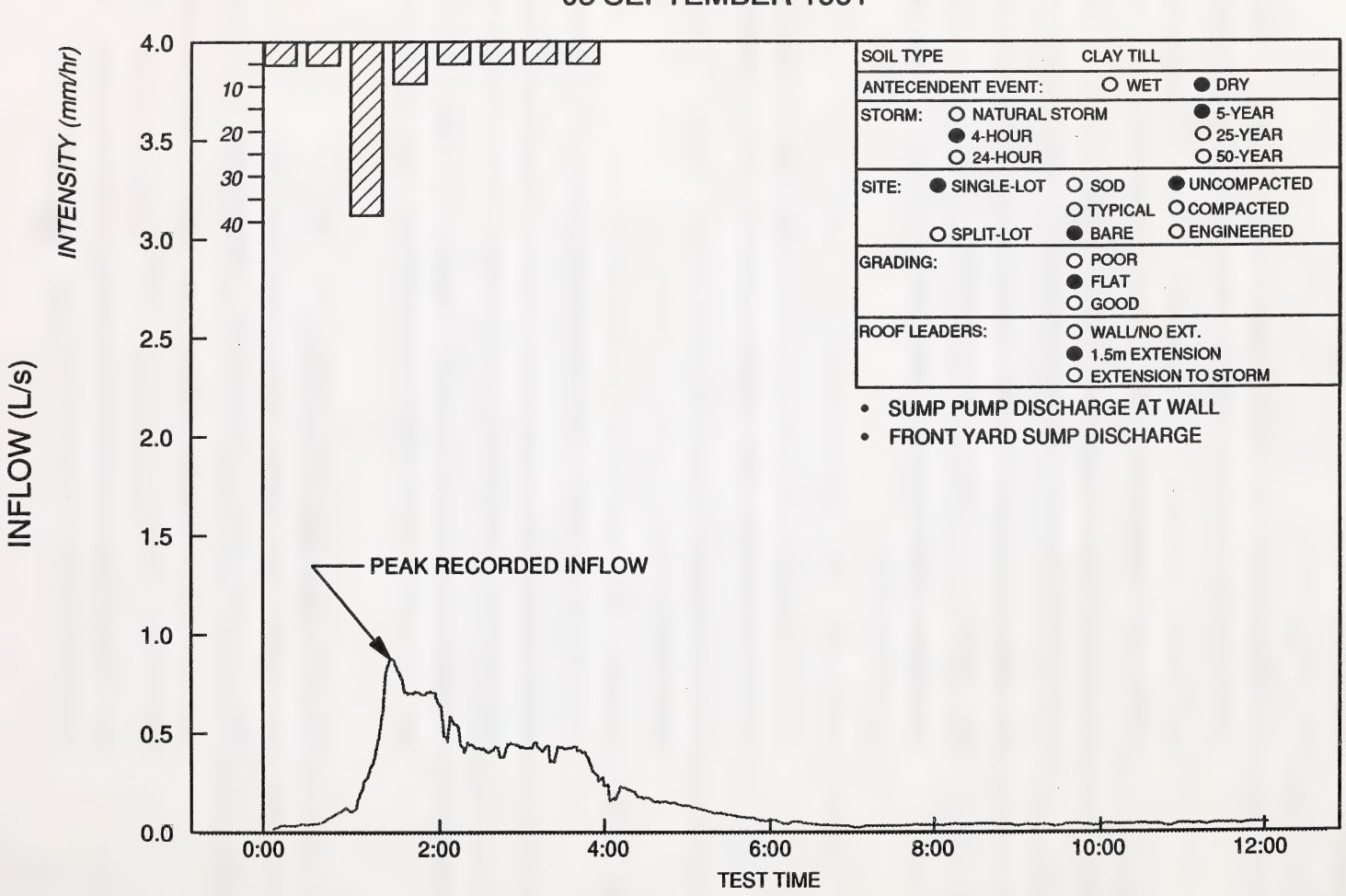


Figure 20a FOUNDATION DRAIN RESPONSE

hatched area at the top, indicating the intensity and duration of the simulated event. The lot characteristics for the simulation are presented in the top right hand corner of the graph.

The response hydrographs show the inflow rate throughout the storm and the area under the curve is the volume of water conveyed through the foundation drain. By dividing the volume of water conveyed by the foundation drain, by the amount of water applied, the percent of water entering the foundation drain is calculated.

Figure 20b: Recirculated Sump Discharge Water

The test of August 26 conveyed the sump discharge water offsite, thus preventing the recirculation of sump water. The subsequent simulations used the same lot characteristics and storm event except the sump discharge location was varied. Accordingly, the difference between the foundation drain responses for August 26, the base test, and the subsequent tests was determined to be recycled water.

Figures 20c and 20d: Sump Pump Cycle Time

As described previously in Section 6.3, the pump running time was monitored by on/off current sensors. For each simulation there is a record of the pump's start/stops and the running time. Figure 20c shows the pump cycle time on the vertical scale; each point is a pump cycle. Figure 20d is the tabulated data of the pump record.

Figure 21: Summary of Simulations

This table summarizes the foundation drain responses of the test program. The site descriptions for each simulation are summarized. The peak recorded

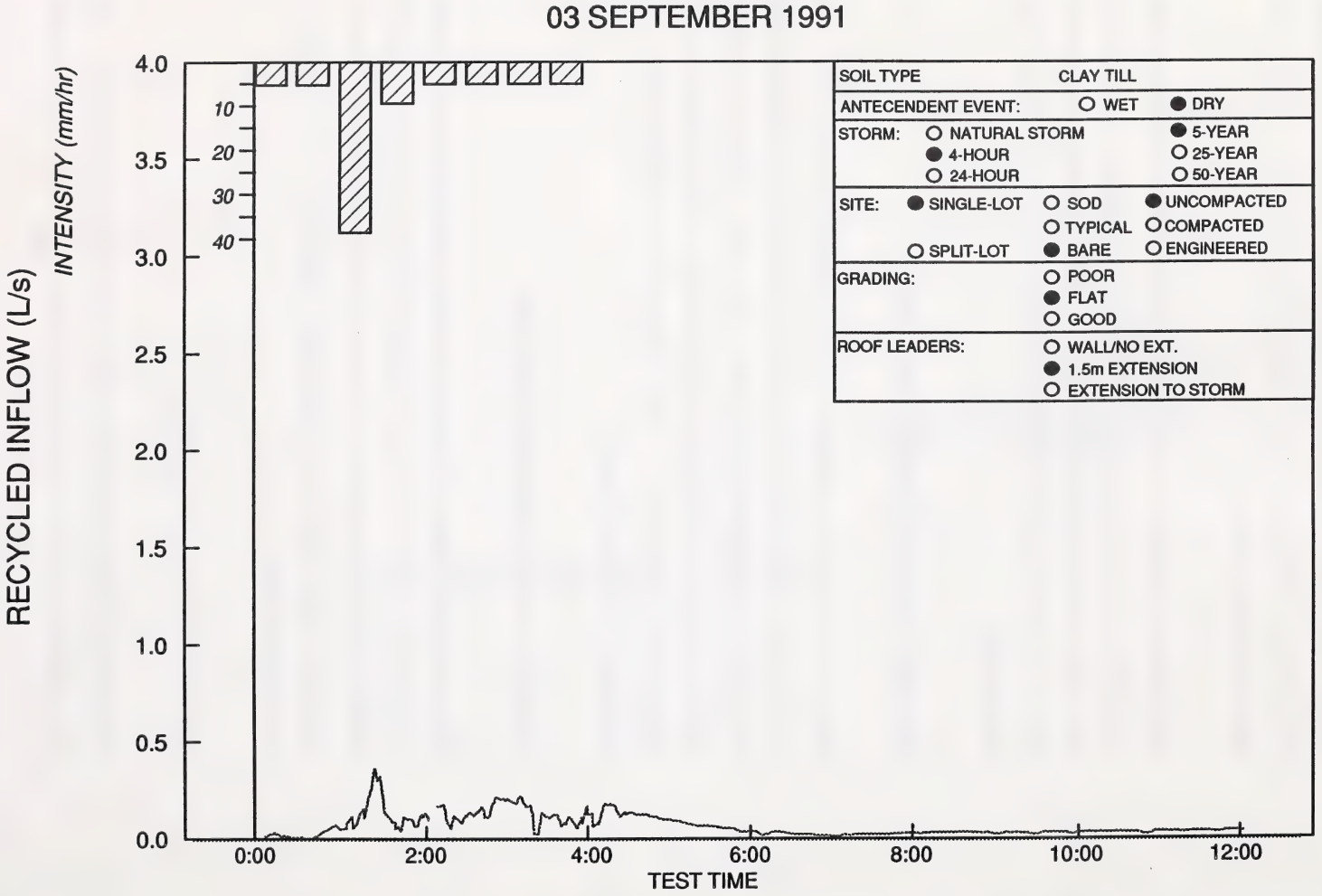


Figure 20b RECIRCULATED SUMP DISCHARGE WATER

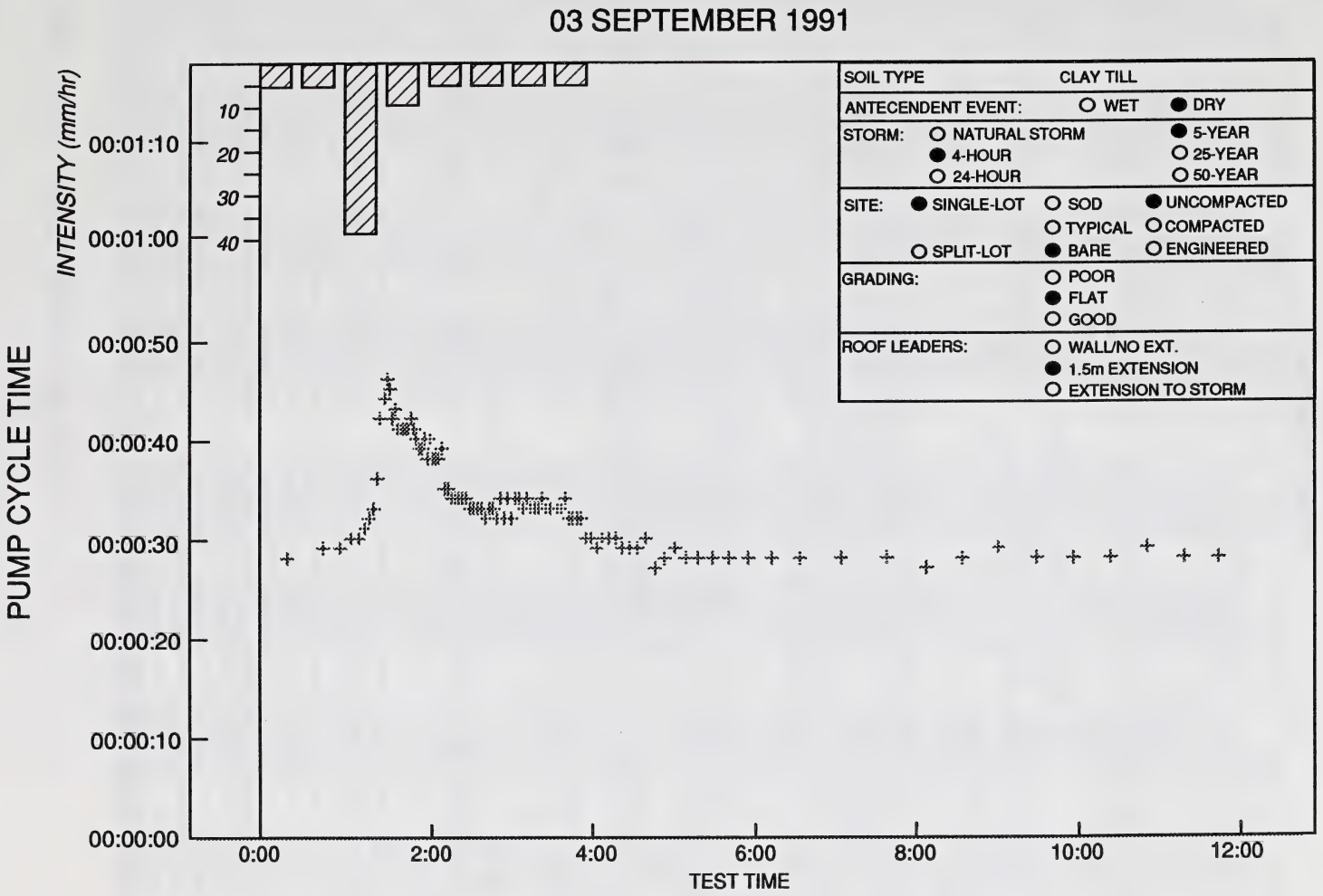


Figure 20c SUMP PUMP CYCLE TIME

CYCLE TIME
FRONT PUMP ONLY

REAL DATE	REAL TIME	CYCLE TIME	TEST TIME
09/03/91	10:00:24	00:00:28	00:20:24
09/03/91	10:26:16	00:00:29	00:46:16
09/03/91	10:38:39	00:00:29	00:58:39
09/03/91	10:46:29	00:00:30	01:06:29
09/03/91	10:51:58	00:00:30	01:11:58
09/03/91	10:56:13	00:00:31	01:16:13
09/03/91	10:59:40	00:00:32	01:19:40
09/03/91	11:02:47	00:00:33	01:22:47
09/03/91	11:05:28	00:00:36	01:25:28
09/03/91	11:07:25	00:00:42	01:27:25
09/03/91	11:11:07	00:00:44	01:31:07
09/03/91	11:12:54	00:00:46	01:32:54
09/03/91	11:14:44	00:00:45	01:34:44
09/03/91	11:16:37	00:00:42	01:36:37
09/03/91	11:18:32	00:00:43	01:38:32
09/03/91	11:20:28	00:00:41	01:40:28
09/03/91	11:22:24	00:00:41	01:42:24
09/03/91	11:24:21	00:00:41	01:44:21
09/03/91	11:26:18	00:00:41	01:46:18
09/03/91	11:28:17	00:00:41	01:48:17
09/03/91	11:30:15	00:00:42	01:50:15
09/03/91	11:32:16	00:00:41	01:52:16
09/03/91	11:34:16	00:00:40	01:54:16
09/03/91	11:36:16	00:00:39	01:56:16
09/03/91	11:38:14	00:00:39	01:58:14
09/03/91	11:40:12	00:00:40	02:00:12
09/03/91	11:42:11	00:00:38	02:02:11
09/03/91	11:44:10	00:00:40	02:04:10
09/03/91	11:46:16	00:00:38	02:06:16
09/03/91	11:48:24	00:00:38	02:08:24
09/03/91	11:50:32	00:00:38	02:10:32
09/03/91	11:52:43	00:00:39	02:12:43
09/03/91	11:55:11	00:00:35	02:15:11
09/03/91	11:57:31	00:00:35	02:17:31
09/03/91	11:59:54	00:00:34	02:19:54
09/03/91	12:02:26	00:00:34	02:22:26
09/03/91	12:05:07	00:00:34	02:25:07
09/03/91	12:07:53	00:00:34	02:27:53
09/03/91	12:10:40	00:00:34	02:30:40
09/03/91	12:13:29	00:00:33	02:33:29
09/03/91	12:16:19	00:00:33	02:36:19
09/03/91	12:19:09	00:00:33	02:39:09
09/03/91	12:22:00	00:00:33	02:42:00
09/03/91	12:24:51	00:00:32	02:44:51
09/03/91	12:27:41	00:00:33	02:47:41
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09/03/91	12:33:14	00:00:32	02:53:14
09/03/91	12:35:56	00:00:34	02:55:56
09/03/91	12:38:40	00:00:32	02:58:40
09/03/91	12:41:23	00:00:34	03:01:23

REAL DATE	REAL TIME	CYCLE TIME	TEST TIME
09/03/91	12:44:10	00:00:32	03:04:10
09/03/91	12:46:56	00:00:34	03:06:56
09/03/91	12:49:44	00:00:34	03:09:44
09/03/91	12:52:32	00:00:33	03:12:32
09/03/91	12:55:18	00:00:34	03:15:18
09/03/91	12:58:08	00:00:33	03:18:08
09/03/91	13:00:57	00:00:33	03:20:57
09/03/91	13:03:44	00:00:33	03:23:44
09/03/91	13:06:31	00:00:34	03:26:31
09/03/91	13:09:19	00:00:33	03:29:19
09/03/91	13:12:06	00:00:33	03:32:06
09/03/91	13:17:42	00:00:33	03:37:42
09/03/91	13:20:31	00:00:33	03:40:31
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09/03/91	13:28:58	00:00:32	03:48:58
09/03/91	13:31:56	00:00:32	03:51:56
09/03/91	13:35:06	00:00:32	03:55:06
09/03/91	13:38:28	00:00:30	03:58:28
09/03/91	13:42:05	00:00:30	04:02:05
09/03/91	13:46:10	00:00:29	04:06:10
09/03/91	13:50:33	00:00:30	04:10:33
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09/03/91	14:10:15	00:00:29	04:30:15
09/03/91	14:15:56	00:00:29	04:35:56
09/03/91	14:21:56	00:00:30	04:41:56
09/03/91	14:28:35	00:00:27	04:48:35
09/03/91	14:35:37	00:00:28	04:55:37
09/03/91	14:43:06	00:00:29	05:03:06
09/03/91	14:51:00	00:00:28	05:11:00
09/03/91	15:10:39	00:00:28	05:30:39
09/03/91	15:22:51	00:00:28	05:42:51
09/03/91	15:37:06	00:00:28	05:57:06
09/03/91	15:54:03	00:00:28	06:14:03
09/03/91	16:14:46	00:00:28	06:34:46
09/03/91	16:45:11	00:00:28	07:05:11
09/03/91	17:18:40	00:00:28	07:38:40
09/03/91	17:47:38	00:00:27	08:07:38
09/03/91	18:14:00	00:00:28	08:34:00
09/03/91	18:40:47	00:00:29	09:00:47
09/03/91	19:08:48	00:00:28	09:28:48
09/03/91	19:35:46	00:00:28	09:55:46
09/03/91	20:02:39	00:00:28	10:22:39
09/03/91	20:29:24	00:00:29	10:49:24
09/03/91	20:55:59	00:00:28	11:15:59
09/03/91	21:21:06	00:00:28	11:41:06
09/03/91	21:44:14	00:00:29	12:04:14
09/03/91	22:09:17	00:00:28	12:29:17

Figure 20d SUMP PUMP CYCLE TIME

SUMMARY OF SIMULATIONS

TEST DATE	START TIME	SITE DESCRIPTION	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN
SEPTEMBER 3	09:40	FRONT DISCHARGE @ WALL, UNCOMP.	0.8777	28.10
SEPTEMBER 5	09:40	FRONT DISCHARGE @ WALL, UNCOMP.	2.7299	155.83
SEPTEMBER 6	12:30	SIDE DISCHARGE @ SPLASH PAD, UNCOMP.	2.3902	130.82
SEPTEMBER 7	11:15	FRONT DISCHARGE @ SPLASH PAD, UNCOMP.	2.7484	73.22
JULY 15	11:00	DISCHARGE TO CONDUIT, COMP.	0.0562	1.41
JULY 16	08:10	DISCHARGE TO CONDUIT, COMP.	0.0672	1.34
AUGUST 26	13:20	DISCHARGE TO CONDUIT, UNCOMP.	0.7005	17.02
AUGUST 28	09:45	DISCHARGE TO CONDUIT, UNCOMP.	1.1219	30.56

APPLIED SIMULATIONS

STORM: 4-HOUR/5-YEAR
VOLUME: 22 040 L
PEAK INTENSITY: 40.38 (mm/hr)

Figure 21 SUMMARY OF SIMULATIONS

foundation drain inflow rate and the percent entering foundation drain are shown in the subsequent columns.

As discussed, one measurable indicator of lot drainage quality, of which sump pump systems are a component, is the percentage of rainfall volume that enters the foundation drain. Another is the foundation drain response which measures the effectiveness of the sump pump system in conveying foundation drain flow away from the residence, as determined by the amount of recycled water. Operational requirements of sump pump systems, including pump reliability and effects of sump water at the discharge locations, were observed and recorded during the testing program.

Figure 21 shows that foundation drain flow varies from 1.34 percent for a well graded site with proper discharge of roof leader and sump water to 155.83 percent for the site with poor backfill practices and sump water discharging at the wall. For tests where the volume entering the foundation drain exceeds 20 percent (based on the August 26 test, with sump discharge offsite, being 17 percent), there is substantial recirculation of sump discharge water through the sump pump system. For example, in the test simulation of September 5, over 155 percent of the rainfall volume applied was conveyed by the sump pump. This test simulated poor backfill and sump pump discharge location practices.

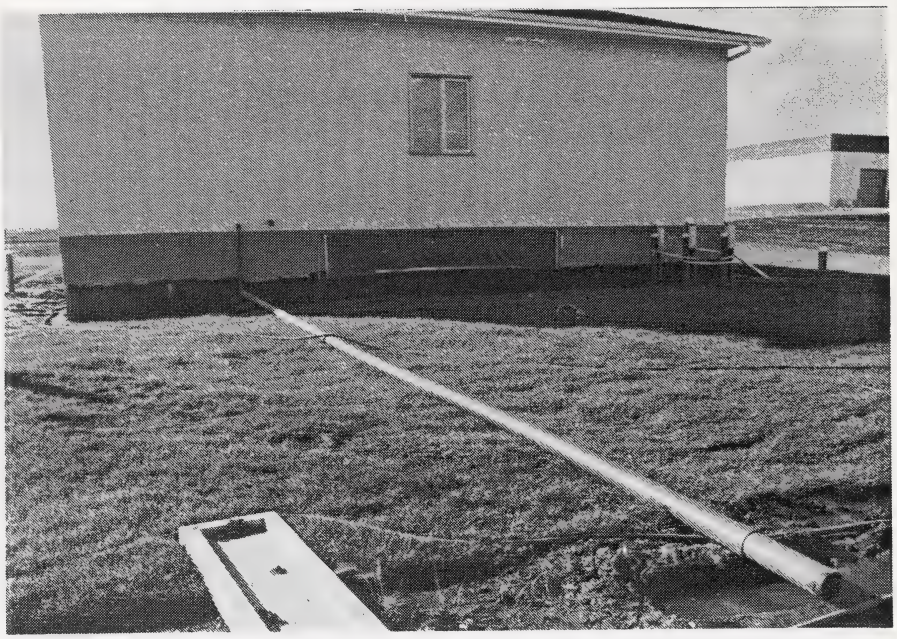
7.2.1 The Discharge of Sump Water

The following sump water discharge location alternatives were tested. They are shown on photographs 12, 13, and 14 and the results are summarized on Figure 22.

- Offsite discharge for compacted backfill conditions on July 15 and 16, 1991
- Offsite discharge for uncompacted backfill conditions on August 26 and 28, 1991
- Front-yard discharge on September 3 and 5, 1991
- Side-yard discharge to splash pad on September 6, 1991
- Front-yard discharge to splash pad on September 7, 1991

Offsite discharge was accomplished by carrying the sump discharge water by closed conduit as shown in Photograph 12. The testing program used closed conduit; however, a drainage swale lined with concrete, asphalt, or any impermeable material would provide similar results.

Photo 12 Sump Discharge Offsite P.V.C. pipe was used to carry sump discharge offsite.



Similar to roof leader discharge, sump water can be discharged adjacent to the foundation wall as shown on Photo 13. Simulations with sump discharge at the wall were done to test the system response for poor discharge practices.

Photo 13 Sump Discharge at the Foundation Wall This photo illustrates sump discharge at the foundation wall.

Discharging sump water onto a precast concrete splash pad is a common practice. The splash pads are available from precast manufacturers and home improvement stores. They come in a variety of lengths from 0.7 m to 2.0 m. Most homes surveyed in the information gathering phase of this study had a 1.2 m splash pad. In the field testing program, a 2.0 m splash pad was used so the sump water would be discharged away from the wall and past the backfill zone.

Photo 14 Sump Discharge to a Splash Pad

Tests that discharged sump water past the backfill zone had significantly less inflow. This is shown on the Foundation Drain Response Summary, Figure 22. Where sump discharge was within the backfill zone, a substantial amount of the inflow was recycled water as documented in Appendix B. The groundwater fluctuations within the backfill zone are presented in Figures 23 and 24.

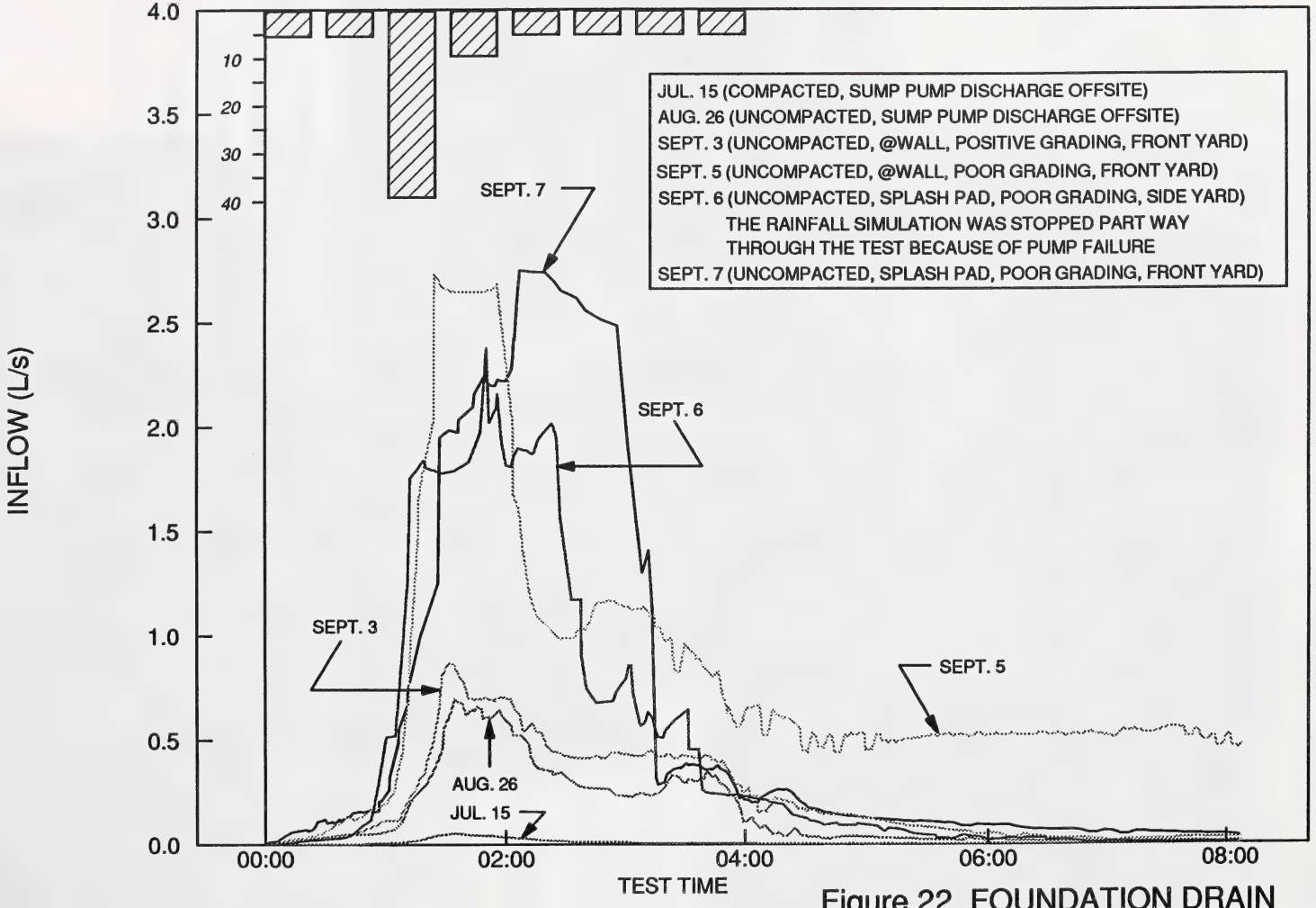


Figure 22 FOUNDATION DRAIN RESPONSE SUMMARY

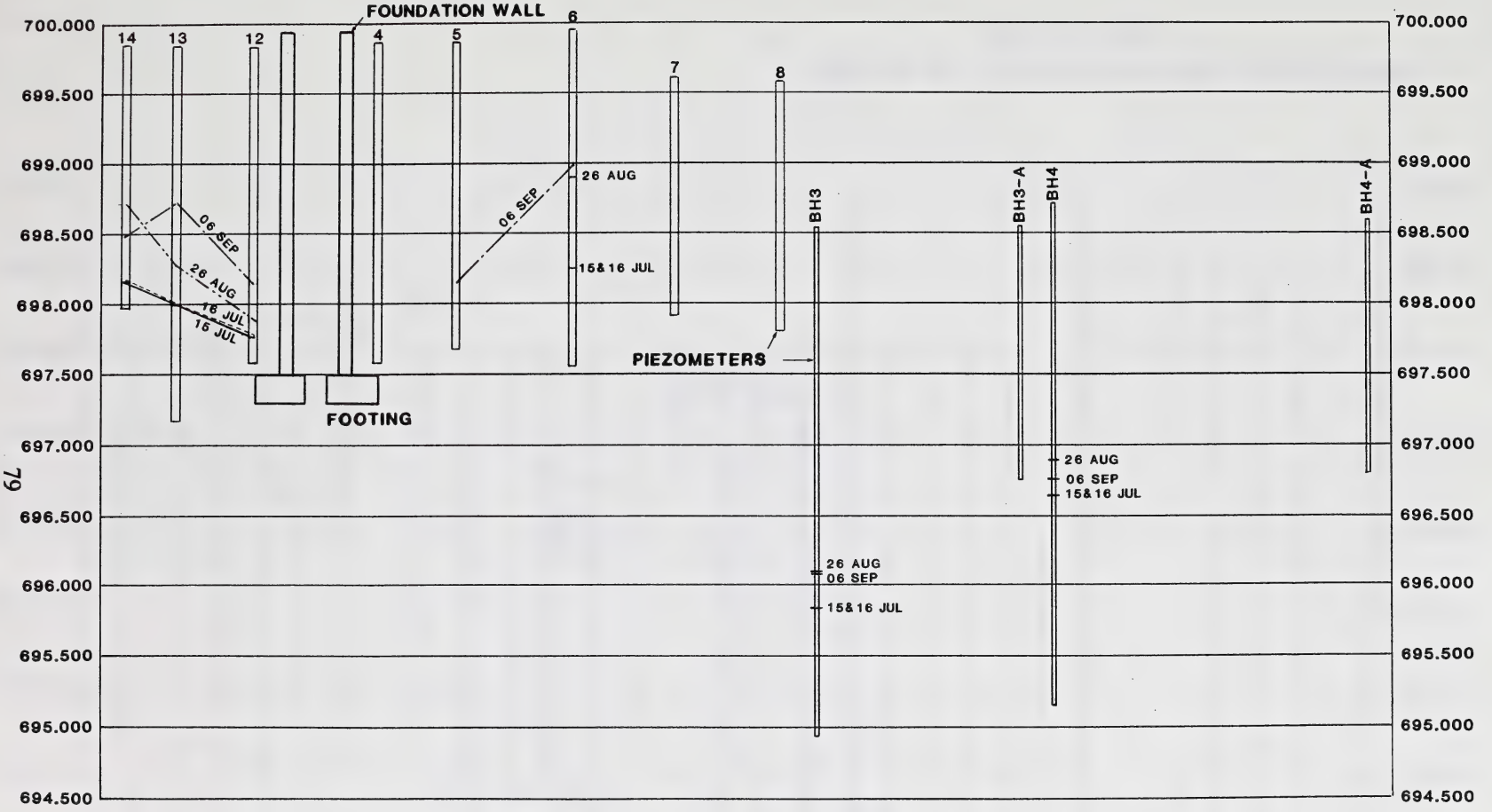


Figure 23 GROUNDWATER ELEVATIONS
FRONT YARD

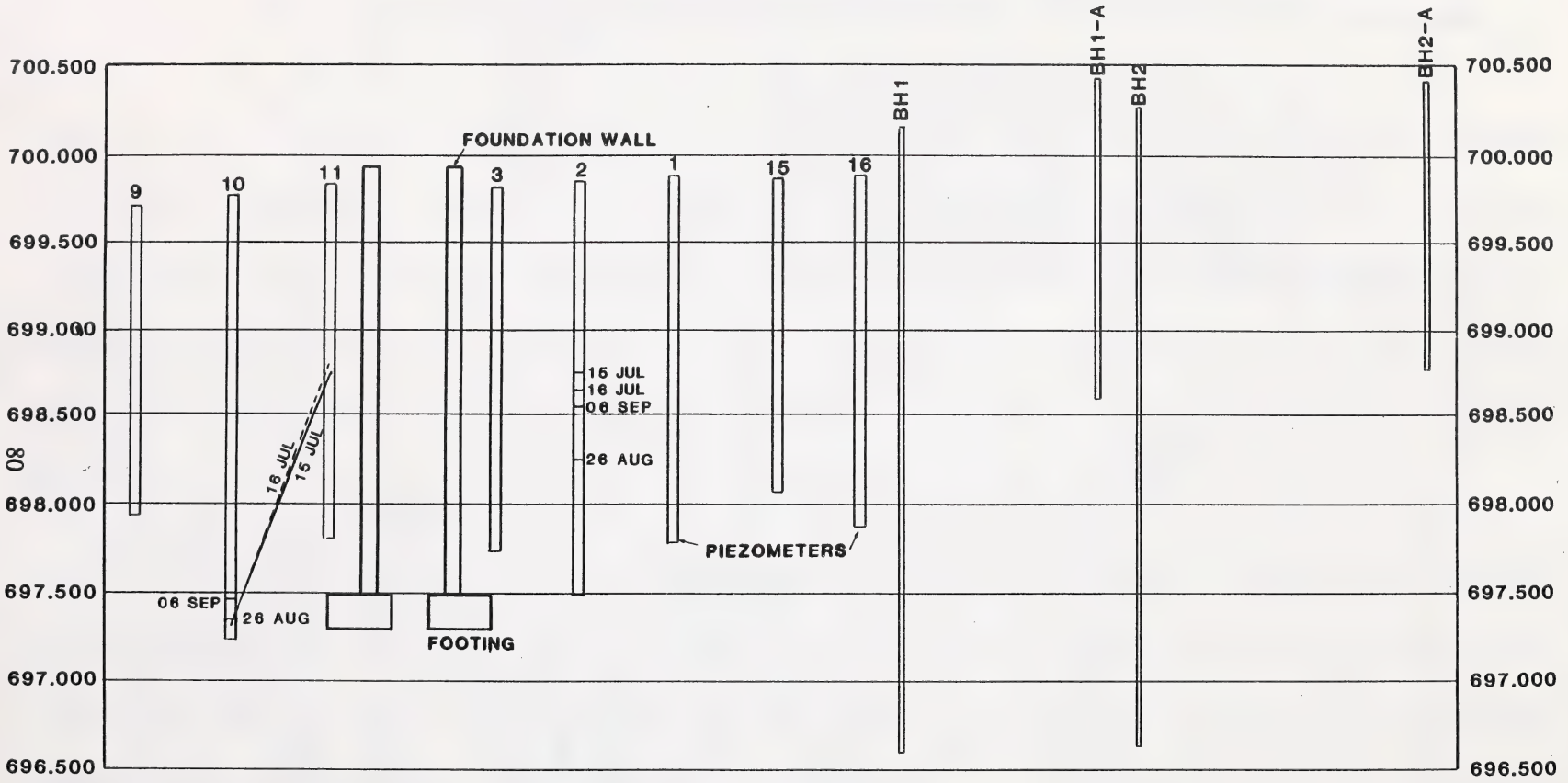


Figure 24 GROUNDWATER ELEVATIONS
BACK YARD

7.2.2 Potential Power and/or Pump Failure

Possible solutions for potential power and/or pump failure were larger sump sizes and a standby pump. Parameters for these alternatives were discussed in Section 5.2 and the testing results are presented in the following two sections.

7.2.2.1 Sump Sizes for Storage Capacity

The time of protection for basement flooding during a power and/or pump failure is dependant on the size of the sump. In this study two sump sizes were tested, 0.96 m^3 and 0.49 m^3. Both sump sizes tested were substantially larger than the National Building Code minimum of 0.19 m^3. If the research facility would have been built with the minimum sump size, basement flooding would have occurred on September 5, 6, and 7, 1991 when the foundation drain inflow rate exceeded the pumping rate.

Detention time available is a mathematical relationship between inflow rate and volume. The total detention volume available was used on several dates as documented earlier in Section 7.1 and in Appendix B. Sample calculations are given in Section 8.0.

7.2.2.2 Standby Pump

A direct current standby pump was tested at the research facility. It was a Simer Model A5000. The product literature is included in Appendix A, while Figure 25 presents the manufacturer's pump curve. The pump is designed to function

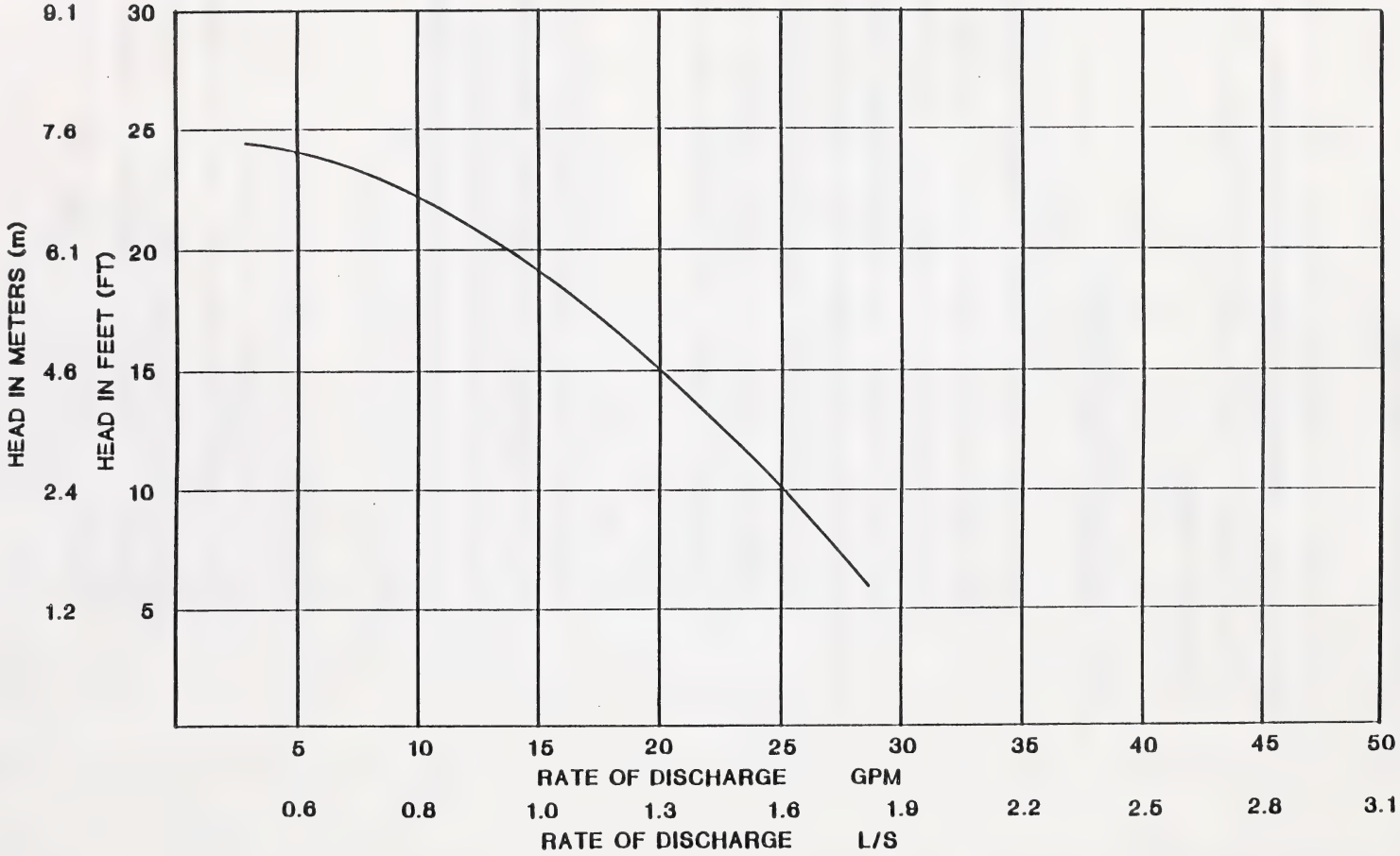


Figure 25 SIMER PUMP CURVE
MODEL A5000

in a single pump installation or act as a backup for another pump. The manufacturer's literature suggests that the pump be used as a backup.

The Simer Model A5000 pump was used at the site on several occasions and the following observations were made:

- The pumping rate is a function of amperage available from the battery. In this work a standard car battery was used. It was observed that the pump labored to reach the head requirement of the system and the rate of discharge was under 1.0 L/s for the given head condition.
- Battery life is a limiting factor on the capacity of this system. During testing the battery-operated system pumped less than 1 m^3 at the system head on a fully charged battery. After pumping approximately 0.13 m^3 of sump water, in 2 min the indicator light for battery recharging came on. A 5-year storm event could yield over 2 m^3 of foundation drain water.
- The connection from the battery case/charger to the pump requires design improvements.
- The required storing of the battery in the home introduces hazards.

The cost of the Simer Model A5000 is approximately $380 plus the cost of a battery.

7.3 Discussion and Analysis of Results

In discussing and analyzing the performance testing of the sump pump systems it is important to remember that:

- Firstly, the sump pump system conveys foundation drain flows only.
- Secondly, foundation drain flowrate is governed by lot drainage characteristics.
- Thirdly, lot drainage characteristics are a component of the overall municipal drainage plan.

The discussion and analysis of the testing program considers these three factors as having significant effects on the interpretation of results and the later recommendations.

7.3.1 Sump Design

The testing program confirmed that sump design is an important component of the system. Sumps should be designed with the specific site conditions in mind.

7.3.1.1 Sump Liners

The side and bottom lining material of the sump can affect sump performance. The sump is subjected to continuous cycles of filling and drawdown; therefore, the liner must tolerate these effects. The facility sumps had concrete sides and gravel bottoms.

Gravel drain rocks in the bottom of the sumps caused pump failure three times during the testing program. During periods of peak inflow (rates in excess of 1.0 L/s) the water in the sump was very turbulent and the drain rock was agitated off the bottom of the sump. Since it is impossible to limit the rate of inflow, proper pump screens or screening of the entire pump assembly would prevent similar system failure.

7.3.1.2 Sump Capacity

Sump capacity tests in this study addressed detention requirements in case of power and/or pump failure. The required capacity of the sump is a function of:

- Foundation drain response that is determined by rainfall intensity and lot drainage characteristics
- Probable length of power and/or pump failure
- Level of service desired

The maximum inflow case during the testing program, on September 7, 1991, was a random event. The rate of inflow exceeded the pump discharge rate for 20 min.; however, the basement did not flood because of the detention capacity available in the sump. The inflow was 2.5 L/s and the pump rate was 1.9 L/s. The approximate detention requirement was 0.6 L/s for 20 min or approximately 720 L. Sump 1 had the capacity to retain this volume and thus prevent basement flooding. In this example the pump did not fail; however, the inflow rate exceeded the pump discharge rate requiring system storage.

Sump sizing, for the purposes of inflow water detention in case power and/or sump pump failure, is a function of total volume available at the time of failure. The amount will vary from:

- The maximum volume available, just after the pump has operated and the pump switch is at the off elevation, and
- The minimum volume available, when the water level is at the pump-on elevation.

7.3.2 Sump Pump

Goulds Model 3871 pumps were installed at the site. Other pumps were tested in the previous phases of this study and the study "Field Evaluation of Foundation Drain Responses". The manufacturers' pump curves for all sump models tested or observed during this project are shown in Figure 26. Some of the pump curves are also located elsewhere in this report. They are included here for comparison. The larger capacity pumps, the Goulds and Hydromatic, were used at installations that had high inflow demands. The Goulds pumps were used at the research facility and the Hydromatic pumps were installed at the multi-family sites. Both of these pumps have a greater design rate of discharge than the more common Little Giant model 6CIA. The Goulds pump has recently been modified by the manufacturer (independent of this project) to improve the inlet screen.

During field testing of the battery powered system, battery life was found to be short. After only 2 min of pumping, battery recharging commenced according to the indicator light. During a power outage the total capacity would be limited to approximately 0.8 m^3 based on these tests. Storm related flows in a power outage could easily exceed this capacity, depending on the intensity and duration of the storm and length of power outage. The Simer pump operated as described in the literature; however, its reliability is related to battery capacity and in areas with very active sump systems, limited protection is provided.

7.3.3. Sump Discharge Alternatives

Testing of sump water discharge locations yielded the following results:

- Grading the backfill zone has the largest effect on sump discharge. For positive grading, very little sump water was

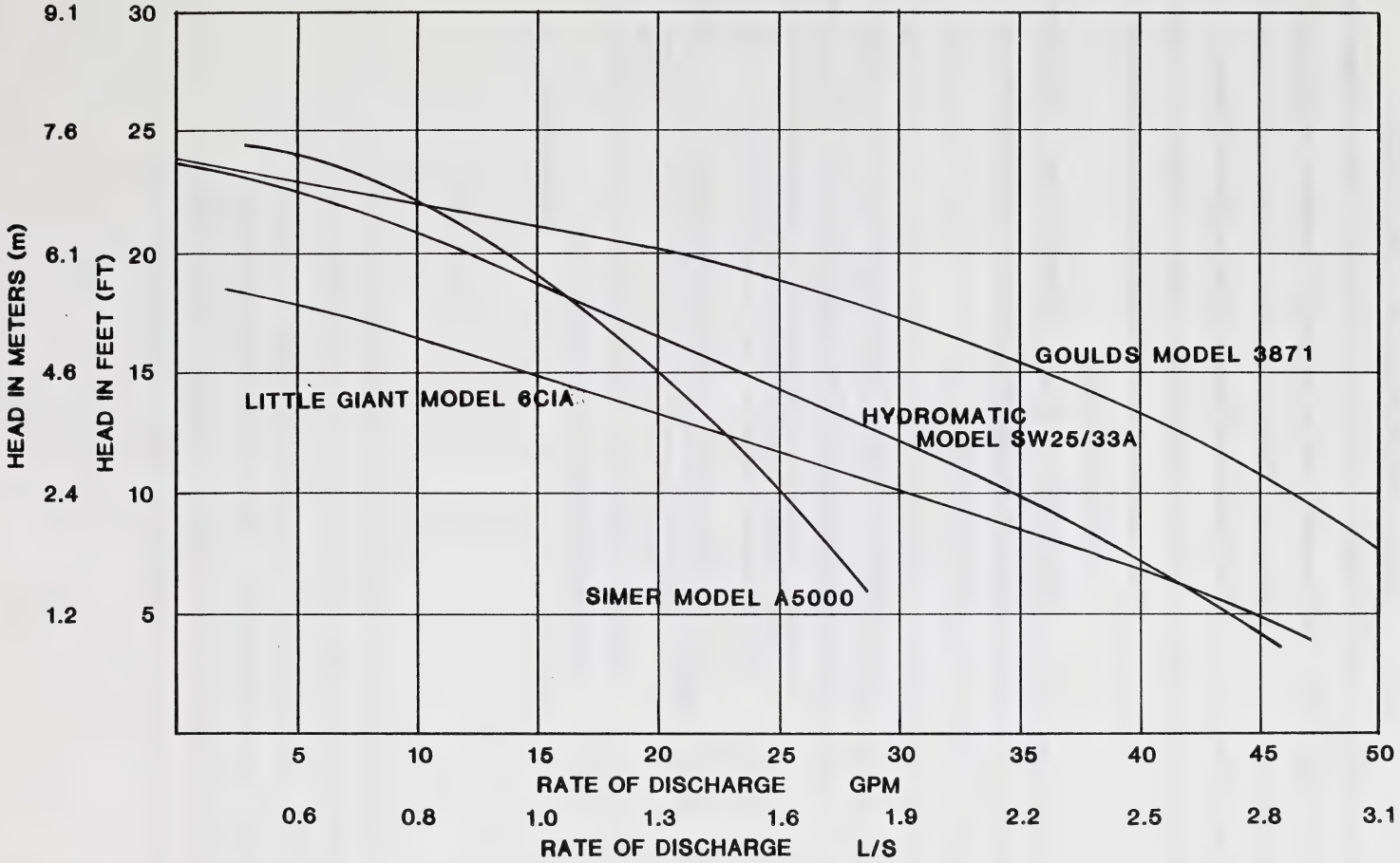


Figure 26 MANUFACTURERS PUMP CURVE

recycled. The amount of sump water recycled increased as backfill zone grading became flatter or negative.

- When sump water was discharged to the side-yard, groundwater fluctuations and an increase in foundation drain flowrates were noticeable. The groundwater level increased 0.2 m over the 4-hour simulation. The sump discharge location was at the back (southwest) corner of the house; therefore, sump discharge water had the length of the side yard to infiltrate and recirculate to the foundation drain.
- When sump water was discharged offsite or when there was positive drainage on site, the rate and volume of recycled water was minimized.

As discussed in Section 5.1, previous studies have evaluated sump pump discharges; observations at the test site confirm that wet areas do develop and there is a high probability of sidewalk/street ice build-up. The homeowners interviewed were aware of the function of the sump pump system; however, they had limited knowledge, if any, regarding how to handle discharge. In areas of clay soils, the discharge of sump pumps to yard surfaces will cause surface inconveniences and the homeowners should be made aware of this.

8.0 PROPOSED SUMP PUMP SYSTEM MODIFICATIONS

Previous studies have quantified volumes of foundation drain flows and many municipal infrastructures do not have the capacity to handle these flows. Traditionally, foundation drain flow has been discharged to sanitary and/or combined sewer systems and sewer backup and basement flooding has resulted. Accordingly, sump pump systems are the approved solution of several municipalities to eliminate foundation drain flows from the sanitary and/or combined sewers.

In this study the analysis of data gathered on operation, and maintenance problems, and related information for residential sump pump systems indicated that the majority of systems work efficiently. The objective of sump pump systems is to eliminate foundation drain flow from sanitary sewers and this task is readily accomplished. However, the identified problems of inconvenience caused by sump discharge water and basement flooding due to power and/or pump failure can be mitigated by improved design, and the establishment of design standards and construction practices.

Sump pump system modifications that were tested at the research site are presented below.

8.1 Sump Design

8.1.1 Sump Liners

The sump should be lined. The test sumps had concrete cast-in-place sides and a gravel bottom. As documented, the drain gravel caused pump failure in turbulent inflow conditions. This problem could be solved by lining the bottom with treated wood or other suitable material. The bottom liner should be permeable to allow for the potential of hydrostatic pressures (the sump bottom is approximately 1 m below the foundation

drain). A permeable bottom would provide a drain outlet for the water below the sump pump inlet, thus allowing the sump to dry.

Alternatively to lining the bottom of the sump, the pump assembly could also be installed in a rigid plastic container within the sump pit as suggested by a contractor. The sides and bottom of the container would be slotted similar to a pump screen. By disconnecting the sump discharge piping, the entire pump unit could be lifted from the sump by the handles on the plastic container. This type of assembly would also make servicing the pump more convenient.

8.1.2 Sump Capacity

The sump component of the sump pump system could be increased in size to provide additional detention capacity, and this reduces the likelihood of flood damage caused by power and/or pump failures. Capacity increase is a simple design modification which reduces the potential of basement flooding during a power failure. An added advantage of increased sump detention is that the impact of the stormwater runoff hydrograph peak is effectively reduced, as presented on Figure 27.

Sump size should be based on the volume that would accumulate over approximately 2 hours at the design foundation drain inflow rate for the subdivision or municipality. The time of detention should be based on the average length of power outage experienced for the location. The detention time of approximately 2 hours used in this report is based on discussions with Edmonton Power. Available storage would depend on the level of the pump "on" switch mechanism set at the time of installation and also on the amount of water in the sump at the time of the failure. The net available storage would be less than 2 hours of flow because of

these factors.

A sample calculation of sump volume is as follows:

Inflow rate (ave.) = 0.15 L/s

Detention time of 2 hours = 120 min

Inflow rate (ave.) x Time = Volume

$$0.15 \text{ L/s} \times \frac{60 \text{ s}}{\text{min}} \times 120 \text{ min} = 1080 \text{ L} = 1.08 \text{ m}^3$$

This is a sample calculation only. The value for the inflow rate would be established for each neighborhood by the municipality considering expected inflow rates for the design storm event (reflecting level of service). The required detention time would be based on average duration of power outages.

The sumps at the research facility were approximately square; however, sump configuration could be adjusted to suit the home. The depth dimension of the sump affects the pump capacity. The deeper the sump, the greater the total head (lift) and the less the discharge rate of the pump.

Sump size and sump dimensions will vary with storage requirements. Minimum sump dimension requirements are provided in the National Building Code and summarized in Section 3.2 of this report. The code requires that the sump be at least 0.75 m in depth and have an area of 0.25 m^2. The depth of the sump should not exceed 1 m when considering pump efficiencies and maintenance requirements of the sump and sump pump. Accordingly, the area of the sump should be large enough to allow easy access for maintenance. To be consistent with the code, the two sump sizes tested were rectangular with the area dimensions being less than or

equal to the depth dimension.

8.2 Sump Pump

The performance of the electric pumps tested in this study was satisfactory. The concerns regarding stuck floats and on/off switches documented during the survey could be resolved by enlarging the sumps and allowing more space to locate wiring and discharge piping. Pump specifications for sump pump systems should meet the following criteria:

- Where sump pump systems are expected to be active, a more robust pump with a minimum capacity of 1.5 L/s at 2.5 m total head is recommended. The more robust pumps are capable of higher pumping rates and continuous service (longer cycle times). For example, the Goulds pumps used at the research site pumped in excess of 150 m^3 and proved reliable.
- The pump should have a screen at the suction inlet.
- The selected pump should be serviced locally with replacement parts readily available.

The battery operated pump performed adequately; however, its cost and limited power supply capacity reduce its viability as a standby pump. For very active sump systems, a larger sump and a standby pump would provide concerned homeowners with additional security. Should this system be employed by a homeowner the battery should be inspected on a regular basis. The supplier and the fire department may suggest safe battery storage methods.

During the information gathering phase of the project it was noted that some homeowners have changed the discharge location of their sump pump system; for example, the discharge was moved from the front-yard to the back-yard. In relocating the discharge location, several pipe bends were required and several meters of pipe added to the system piping. This increased pipe length increases

the total system head and reduces the rate of discharge. In summary, the shorter the length of discharge pipe from the sump, the greater the pump capacity.

There are several reputable manufacturers of pumps and this study does not recommend a specific pump. Four different makes of pumps were tested and all operated satisfactorily.

8.3 Sump Discharge Alternatives

Saturated lawns and potential street/sidewalk icing are the most common problems of sump pump systems. During the survey, sump discharge was the most identified problem by homeowners with active sump pump systems. Observations made during field testing confirmed the inconveniences caused by sump discharge water. Except in neighborhoods where sump pumps are connected directly to storm sewers, onsite discharge of sump water becomes a component of the sump pump system as recognized in Section 3.2 of the report.

Sump pump systems commonly discharge foundation drain flow to the yard surface. In the Edmonton area, there are active sump systems discharging to clay soil and in these instances, the sump discharge water constitutes a nuisance. Present practice suggests that the builder/homeowner should discharge sump water to the ground level just beyond the backfill zone, although the location of the discharge is usually selected by the mechanical contractor. Yard grading and landscaping are not commonly designed to accommodate discharged sump water. Since sump water is being discharged to the yard surface, the handling and conveyance of the sump water should be considered a component of the sump pump system. Average sump water discharge rates are approximately 1.9 L/s (pump discharge rate) and this amount of water will negatively impact a site that is not designed to handle it. Because of the possible volume of sump water and

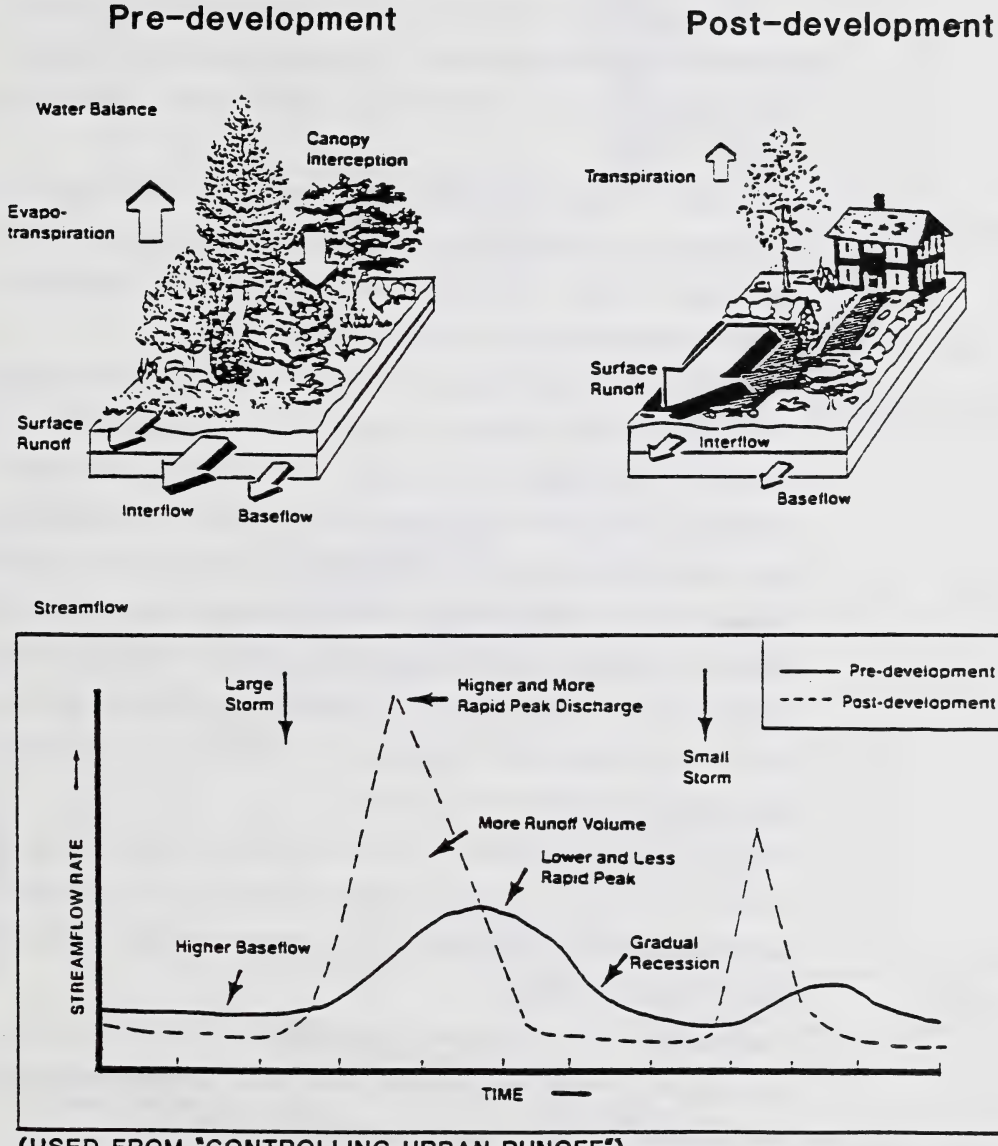
the identification of its discharge as a problem, current onsite stormwater management concepts have been considered in the report.

Recent approaches to urban drainage engineering have an objective of limiting the environmental impact of urbanization. The impact on hydrology is illustrated in Figure 27. Several municipal drainage plans are incorporating the concept of onsite retention/detention of storm water to achieve this objective. The incorporation of designed onsite detention for foundation drain flow is therefore presented as a possible solution.

Design modifications for the current practice of surface discharge of sump water could reduce onsite stormwater problems. The current practice is to use the landscaped area adjacent to the discharge pipe as an infiltration site. In some instances the sump water is discharged onto driveways or similar impermeable surfaces and carried directly to the roadway. In areas with active sump systems this caused greater risks than discharging to landscaped areas, because of the icing problem on common travelled areas of the lot. The location at which the sump exits the foundation varies and for some homes that location increases the problems caused by sump water discharge, by lengthening the surface drainage path.

Onsite solutions for sump water discharge were determined to be the most viable alternatives. Onsite solutions for conveying and handling discharge water are a requirement of the National Building Code. By designing onsite control of discharge water, the location is defined and the infiltration area is pre-planned. The risk of street and/or sidewalk icing is reduced by providing a designed detention basin. The simple transfer of drain flows from the sanitary system to the storm system was not evaluated in this study.

The following proposed system modifications and policies for sump water



(USED FROM "CONTROLLING URBAN RUNOFF")

Figure 27 CHANGES IN WATERSHED HYDROLOGY AS A RESULT OF URBANIZATION

discharge reflect the magnitude of the problem and present the alternative of formalizing onsite control:

- Foundation drain flows should be considered stormwater and be included in stormwater management practices. Foundation drain flows are generally rainfall induced and the flowrate and related system impacts are significant.
- Similar to roof leader flow, foundation drain flow results from lot development. Previous studies have documented the magnitude of their contribution to runoff. Both should be defined as point source contributors to the overall drainage plan on a lot-by-lot basis.
- Within the subdivision drainage plan and further detailed lot drainage plans, the discharge locations of sumps and roof leaders should be designated. As designated components of the drainage system, their inclusion in the overall storm system design would be a requirement. Subdivision drainage plans and subsequent plans should provide a defined drainage course for the discharge water of sump pump systems and roof leaders as suggested by the National Building Code. Similar to grading within the backfill zone, planned lot grading to convey sump discharge water and roof leader water would then be inspected by the jurisdiction having authority.
- Onsite stormwater management of sump water and roof leader water would benefit receiving streams (both natural and manmade). Infiltration/detention basins should be considered a feasible method of onsite stormwater control.
- The backfill zone at the location of sump discharge should be graded at a minimum of 7 percent and the sump water should discharge to a splash pad or similar structure to carry water past the backfill zone.

Figure 28 illustrates the foregoing concept. The illustration shows subsurface drainage for the infiltration/detention basin; however, for residential lots not

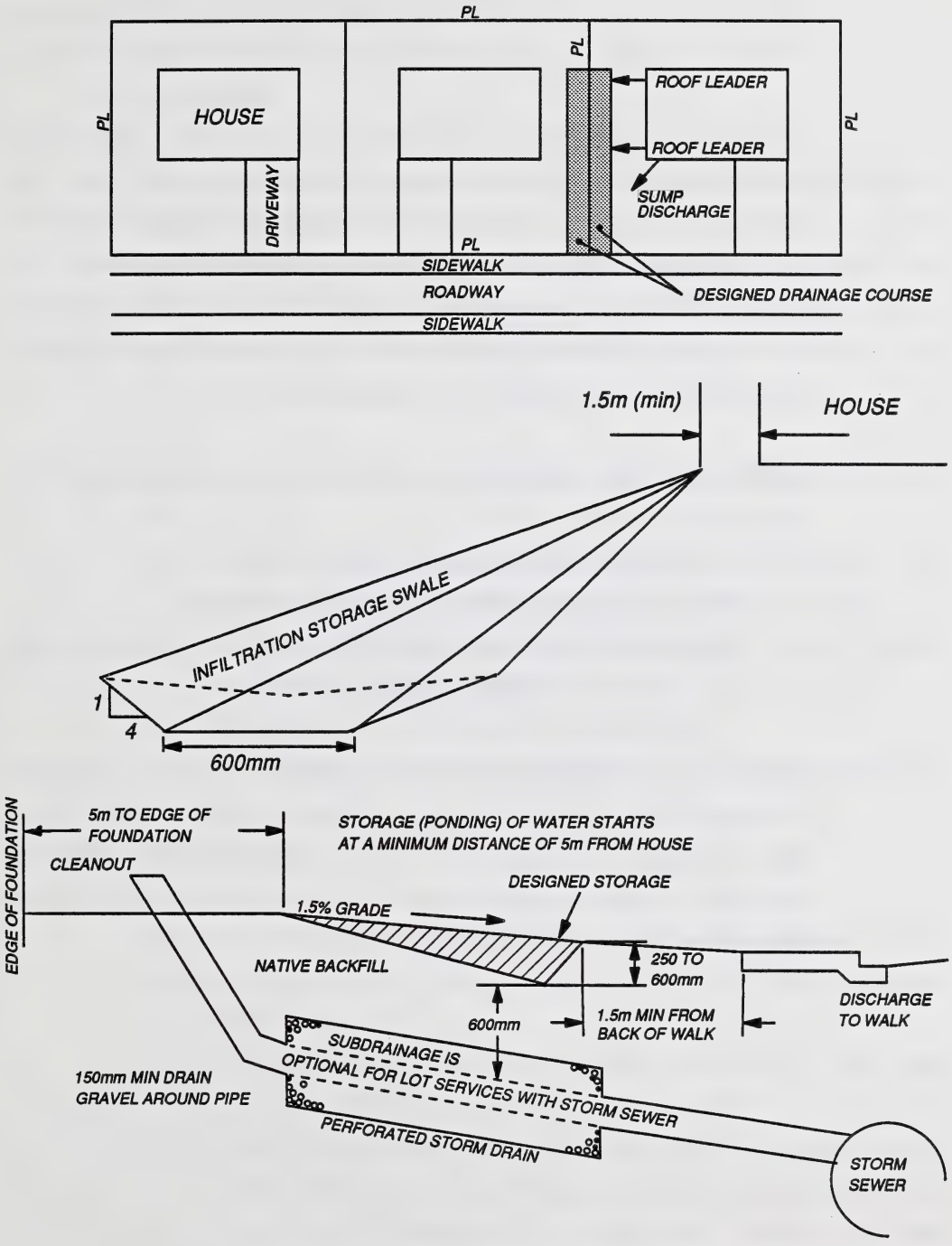


Figure 28 SMALL SITE INFILTRATION STORAGE SWALE

serviced by storm sewers, the basin would be increased in size. The basins should be sized so there is no standing water after 48-hours for a 5-year storm event.

The infiltration storage swale allows the homeowner with a sump pump system to design and landscape the area designated to receive the sump water. By providing a designated area for sump water discharge, the dimensions (extent) of the saturated lawn could be controlled thus easing maintenance problems. For example, if the width of the saturated part of the basin is designed to be less than 1.5 m, the swale could be mowed from the side, thus avoiding the need of walking through the soggy area during lawn cutting.

Municipalities having experience with small site detention basins suggest the following care and maintenance:

- Use a hydrophilic grass seed mixture in the detention swale.
- Remove debris such as leaves, grass clippings, and silts.
- Should surface clogging of the topsoil develop as the facility ages, removal and replacement will restore infiltration capacity.

This planned method of sump water discharge would reduce the peak in the runoff hydrograph, thus reducing storm system requirements and the impact on the receiving stream. The application of the concept of onsite stormwater management is expanding and formalizing the existing practice of sump water discharge and addresses the intent of the Building Code.

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

It was concluded that sump pump systems that discharge to surface adequately convey foundation drain flow, though some problems are created. The essential problems identified with the current sump pump systems are inconvenience from the effects of discharge water and power and/or pump failure. Through improved design standards and construction guidelines, the problems identified with sump pumps could be resolved.

The field program tested sump pump system modifications. The findings indicate that:

1. Sumps should be lined to prevent the sloughing of material from the sump sides and prevent the possible plugging of the pumps by the soils.
2. The larger the volume of the sump, the greater the protection provided from power and/or pump failure.
3. The sump pumps tested performed satisfactorily.
4. Sump water discharge areas must be planned to minimize inconveniences.

9.2 Recommendations

The performance of sump pump systems could be improved through system modifications and implementation of design standards. The following measures are recommended:

1. The sump should be totally lined. Concrete, treated wood, or plastic could be used, and the bottom should have drainage holes.
2. For active systems, the sump should have sufficient storage volume to detain foundation drain water for approximately 2 hours, based on a design rate of inflow established by the municipality for the areas and/or

neighborhood. The minimum sump volume should be 0.5 m^3 for less active sump pump systems. This size, substantially larger than the minimum recommended by code, will more readily facilitate the floats and cables and accommodate maintenance.

3. Sump pumps should be durable and capable of pumping a minimum of 1.5 L/s at 2.5 m of total dynamic head.
4. Discharge from sump pump systems and roof leaders should be defined as stormwater and be considered appropriately within the lot drainage plan and the subdivision drainage plan.
5. The locations of sumps, sump pump discharges, and roof leaders should be identified and designed on the house plans. Issuance of a building permit would then consider these components as to their conformance with the lot drainage plan and Section 9.14 of the National Building Code.
6. Onsite management of sump water and roof discharge within designated areas, such as onsite infiltration/detention basins, represents a workable alternative to direct surface conveyance to a minor or major storm system, and could in many instances work in consort with a surface conveyancing regime.
7. The issues of standards and regulations of sump pump systems should be addressed by the housing industry so that system requirements fall within one jurisdictional area, such as the building code, and consequently can be enforced.

The recommended system is presented and summarized on Figure 29, Recommended Sump Pump System.

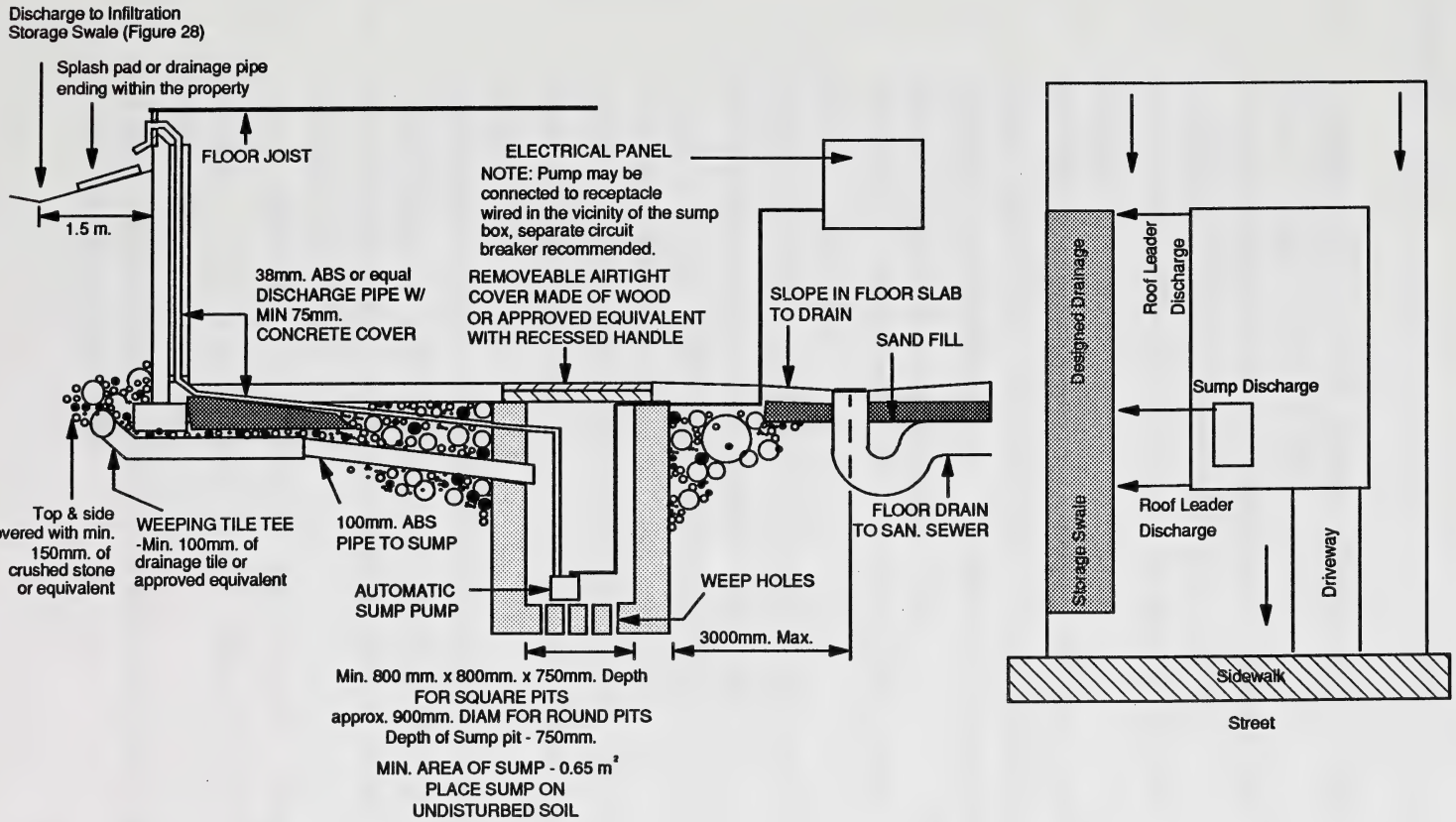

Discharge to Infiltration Storage Swale (Figure 28)
Splash pad or drainage pipe ending within the property
FLOOR JOIST
1.5 m.
ELECTRICAL PANEL
NOTE: Pump may be connected to receptacle wired in the vicinity of the sump box, separate circuit breaker recommended.
38mm. ABS or equal DISCHARGE PIPE W/ MIN 75mm. CONCRETE COVER
REMOVEABLE AIRTIGHT COVER MADE OF WOOD OR APPROVED EQUIVALENT WITH RECESSED HANDLE
SLOPE IN FLOOR SLAB TO DRAIN
SAND FILL
Top & side covered with min. 150mm. of crushed stone or equivalent
WEEPING TILE TEE -Min. 100mm. of drainage tile or approved equivalent
100mm. ABS PIPE TO SUMP
FLOOR DRAIN TO SAN. SEWER
AUTOMATIC SUMP PUMP
WEEP HOLES
3000mm. Max.
Min. 800 mm. x 800mm. x 750mm. Depth FOR SQUARE PITS
approx. 900mm. DIAM FOR ROUND PITS
Depth of Sump pit - 750mm.
MIN. AREA OF SUMP - 0.65 m²
PLACE SUMP ON UNDISTURBED SOIL
SUMP PIT MAY BE CONSTRUCTED OF:
a) Concrete
b) G.M.V. Steel
c) Pressure treated wood
d) Approved A.B.S. or P.V.C. or equal
SUMP PUMP INSTALLATION
Designed Drainage
Storage Swale
Roof Leader Discharge
Sump Discharge
Roof Leader Discharge
Driveway
Sidewalk
Street
LOT DRAINAGE PLAN

Figure 29 Recommended Sump Pump System

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APPENDIX A

INFORMATION GATHERING

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1. RESIDENTIAL SECTOR

1.1 Single-Family Dwellings

A telephone questionnaire was conducted from October 15, 1990 to November 16, 1990, which contained questions for Sherwood Park residents on sump pump system operations. The summarized questionnaire is as follows:

SAMPLE SIZE = 40

1. QUESTION: Has your sump pump ever run for an unusual amount and if so, what was the weather condition?

   Yes = 12

   9 respondents claim that their sump pumps operated for an unusual amount of time during or immediately following a significant rainfall event.

   3 respondents claim that their sump pumps operate two or three times daily, regardless of weather conditions, throughout the year.

2. QUESTION: List any maintenance, repairs, or modifications which you have made to your sump pump system:

   2.1 Maintenance: Yes = 1

   1 respondent frequently checks, sometimes as often as once a

day, to determine if sump pump system is operating correctly.

2.2 Repairs: Yes = 7

5 respondents reported that their sump pump had to be replaced.

2 respondents stated that stuck floats had to be freed.

2.3 Modifications: Yes = 21

12 respondents reported that Strathcona County installed bypass valves.

9 respondents stated that they extended the discharge location away from their home via a hose or underground pipe.

SURVEYOR'S COMMENTS:

1. *All of the respondents, with the exception of one person, do not inspect or perform preventative maintenance on their sump pump systems. The only time these persons made an effort to assess the condition of their sump pump system was when the pump required replacement or repair because of failure.*

2. *Although only nine respondents stated that they extended the sump water discharge location away from their homes, it is believed that this is standard practice among homeowners. Upon reviewing all of the questionnaires, the most common complaint focused on the inadequacy of sump pump discharge control. All of the respondents, even those with inactive sump pumps or those who altered discharge locations, are opposed to discharge that occurs next to the home whether it be onto a splash pad or onto the lawn.*

3. One of the nine respondents that extended the sump water discharge location away from the home, stated that during the winter months, automotive antifreeze is added to the water in the sump pit to prevent the extended discharge line from freezing.

3. QUESTION: List and describe the types of maintenance and repairs with their related costs.

Description	Costs
Sump pump unit	Homeowner installed: Approximately $140
	Professionally installed: $250 to $300

4. QUESTION: Does the sump pump have an effect on the livability of your home?

Yes = 10

3 respondents did not specify why the sump pump system affected the livability of their homes.

4 respondents complained of noise produced while the sump pump was operating.

3 respondents were concerned that the sump pump would experience mechanical or power failure resulting in basement flooding.

5. QUESTION: Would you choose a home with a sump pump if you had to move?

Yes = 19
Indifferent = 11
No = 10
40

6. QUESTION: List any problems you have with your sump pump.

Total = 19

8 respondents claim that when sump water is discharged adjacent to their home, either onto a splash pad or onto the lawn, it destroys grass and vegetation or it causes other unacceptable inconveniences.

7 respondents complained of mechanical problems; two persons reported stuck floats and five reported that the entire sump pump had to be replaced.

3 respondents said that their sump pumps ran unusually often causing concerns about mechanical failure due to frequency of operation.

1 respondent stated that the bottom of the sump pit was filled with weeping tile rock and a combination of silt and clay.

7. QUESTION: Are you aware of the function and need for a sump pump system?

Yes = 36
No = 4
40

7.1 If yes, briefly describe your interpretation of the need for a sump pump system.

Of the 36 persons answering in the affirmative, they all believed sump pump systems either prevented the basement from flooding or removed water from the weeping tile and the foundation area.

SURVEYOR'S COMMENTS: *The 36 persons who are aware of the function and need of a sump pump system understand that their homes have a sump pit and sump pump that function together to remove water from the basement area. The majority of these persons, had little knowledge of how the sump pump system should be maintained.*

1.2 Multi-Family Site

Through the cooperation of the condominium associations of the two developments, 15 homeowners completed questionnaires.

1. Question: At your place of residence are you satisfied with the present location of the pipe/hose that discharges sump water? (i.e., Does the water exiting the pipe/hose destroy grass or cause any other inconveniences?)

   14 respondents were dissatisfied with the location of the discharge of sump water.

   1 respondent was satisfied.

2. Question: Suggest any alternative methods(s) of discharging sump water other than the method presently employed at your place of residence.

11 respondents suggest connecting to the sewer with five respondents stating storm sewer.

2 respondents did not suggest an alternative.

2 respondents felt the current system is acceptable.

3. Question: At your place of residence does the sump water exiting the discharge pipe/hose ever cause sidewalks or roadways to be covered with ice during the winter months?

14 respondents said the sump discharge causes ice buildup on the roadways and believe it causes dangerous conditions.

1 respondent said icing not a problem

SURVEYORS COMMENT: *The majority of the respondents stated that these are "seniors" developments and the icing problem is therefore magnified.*

2. MANUFACTURING AND SUPPLY SECTORS

2.1 Suppliers

A questionnaire was mailed to two suppliers of sump pumps. It has been summarized as follows:

QUESTION: What is the most popular type of sump pump (please include manufacturer, pump series, and any identifying product or serial numbers.)

A. With homeowners?

Supplier 1 - Little Giant Pump Company
Little Giant 5ASP or 6CIA Submersible Sump Pump
1/6, 1/4, or 1/3 Horse Power (HP)
Complete with Diaphragm Switch

Suppliers Note: "We have found the cheaper upright column type sump pumps to be unreliable and awkward to install. Therefore, we don't sell or recommend them, even though they are still very popular with bargain shoppers."

Supplier 2 - Little Giant Pump Company
Little Giant 5ASP or 6CIA Submersible Sump Pump

B. With building and/or plumbing contractors?

Supplier 1 - Little Giant Pump Company
5ASP, 1/6 HP, Submersible Sump Pump
(This is the "most inexpensive series.")

Supplier 2 - Little Giant Pump Company

6CIA Submersible Sump Pump

- S.R. Water Systems
  Model S300E Sump Pump

SURVEYOR'S COMMENTS: Supplier 1 stated that the contractors' preferred sump pumps are the least expensive models. Conversely, Supplier 2 claimed that the contractors' preferred sump pump is a more heavy duty and reliable model.

QUESTION: In relation to the above question, what parts and/or accessories are most commonly replaced or maintained, and what are there related costs.

Supplier 1 - Diaphragm Switch
Parts $15.00
Parts and Labour $35.00

- Clean-out Pump $14 - $18

Suppliers Note: "This condition is common (cleaning out sump pumps) as many sumps are not true sumps, just a hole in the concrete floor with just a pail etc., allowing dirt and sand to clog the pump."

Supplier 2 - Remote Switch Assembly or Mercury Float Switch
Replacement Cost Approximately $58.00

2.2 Manufacturer - Sump Pumps

During the data gathering process of this study the Little Giant Pump Company, Oklahoma City, Oklahoma, USA, was contacted. A questionnaire was forwarded on November 27, 1990 and is summarized as follows:

Question: What are suggested installation guidelines in terms of:

A. Sump Pump

"Suggested pit capacity is 18" diatmeter by 24" depth. No less than 18" depth. 20 - 26 gallon capacity (U.S.)".

B. Construction and protective surfacing (i.e. Geotextiles, concrete) of sump pit walls and bottom?

"Sump pit construction is commonly concrete, fiberglass, polyethylene, or polypropylene."

Question: What sump pump parts and accessories are most commonly replaced or maintained,and what are their related costs?

- Automatic Switch replacement kit $11.00 to $18.00 (excluding labour)

Question: Generally which Little Giant Residential Sump Pump is the most popular with homeowners, and plumbing or homebuilding contractors?

Model 6CIA, 1/3 HP, 1½" discharge, automatic switch

3. CONTRACTORS

CONTRACTOR 1

Mechanical: Plumbing and Gas Fitting

This contractor clearly stated his opinions about sump pump systems indicating that "no one likes them, but the City of Edmonton has a bylaw that says that we must have them". The only other constructive information he offered was a method of discharging sump water to an alternate location on the lot utilizing a pipe or a hose. He believes that if a homeowner wishes to relocate the discharge away from the area immediately adjacent to the home, it should be accomplished by connecting a corrugated flexible polyurethane pipe, of unspecified diameter, to the discharge pipe. He feels that utilizing a garden hose to produce the same result is unacceptable because:

- The garden hose can be easily obstructed or damaged in such a manner as to inhibit sump pump discharge.

- The garden hose can be easily removed, or relocated to discharge in an alternate location, by a disapproving neighbour. It is believed that the rigid corrugated pipe would reduce these incidents from occurring because of its sturdy construction.

CONTRACTOR 2

Mechanical: Plumbing and Gas Fitting

This contractor stated that there are no provincial or municipal standards or codes that regulate the installation of sump pumps or foundation drainage systems. The contractor feels that the installation of these systems is not

policed or inspected properly. As a result certain contractors "put in anything they want", which frequently means, "installing the cheapest sump pump system on the market". In addition, homeowners cannot defend themselves against these questionable contractors because they are not informed as to what comprises an acceptable sump pump system.

The following is a list of suggestions and opinions in relation to sump pump systems expressed by the contractor:

- During home construction, determine if there are significant flows in the weeping tile which must ultimately be discharged by the sump pump. Since it is unlikely that lot grading has occurred, the discharge location should be extended away from the home by connecting a corrugated flexible plastic pipe to the discharge pipe. This connection would prevent water from collecting around the foundation area and recirculating through the foundation drainage system. Care should be taken to remove the corrugated hose upon completion of construction. New homeowners tend to leave it connected whereby it freezes in winter restricting discharge. It was reported that some homeowners left the hose connected because they did not know what purpose it served.

- Typical sump water discharge is accomplished by a piping system that originates at the pump outlet. This system transports effluent through a series of glued plastic pipe sections. It is possible, due to uncontrollable circumstances, that these glued sections could separate or leak. Since part of this piping system is commonly under the floor slab, repair would be troublesome and costly. As an alternative, this contractor installs a 75-psi continuous 1.5-in. polyurethane pipe which extends from the sump pump outlet to the exterior of the home where it acts as a discharge pipe. It is believed that this system of handling

pump effluent is more cost effective and reliable than the aforementioned system.

CONTRACTOR 3

Damp Proofing - Weeping Tile

A questionnaire was mailed to this contractor and was returned on December 10, 1990. The following is a reproduction of the questionnaire:

1. QUESTION: What are suggested installation guidelines in terms of:

A: Sump pit capacity?

B: Construction and protective surfacing of sump pit walls and bottom?

"It is my opinion that sump pit liners are better without a bottom. At present we use both pressure treated plywood boxes and plastic ones. We suggest using the wooden ones (the material that is used is sufficient and economical as well) or else drilling holes in the bottoms of the plastic ones so water can seep in because where there is a high water table there is difficulty in keeping the plastic liners down, the water pops them out of the ground. Whereas the wooden ones allow ground water to filter in, thus helping get the water table down."

"We suggest that the water be piped farther away from the house instead of dropping it along side the basement and just having it recirculated.

2. QUESTION: What is the suggested optimum size of sump and pump and related time for discharge?

"We are using 30-inch deep liners and I think these are sufficient, the bottom of the box is approximately 24 inches below the bottom of the footing. I can not see any advantages to going to deeper ones."

3. QUESTION: What are suggested methods of handling, and locations for discharging sump water?

"Our wooden liners are 2 feet square and the plastic ones are 2 feet across. We feel that the liners that we are using are sufficient in size except where there is a water problem, a high water table or underground stream. In these cases I feel that they can be handled individually as the case arises and increased in size if necessary."

"In my opinion I would say that it is more important that the right size of pump be used to handle rapid flows. I have seen some pumps with a garden hose discharge. I believe we should have a minimum size for pumps"

4. QUESTION: What are suggested methods of dealing with sump pit bacteriological problems?

"I would suggest that every sump should be rinsed out and disinfected periodically with a strong commercial disinfectant."

4. REAL ESTATE

Two real estate services responded to a questionnaire, which is summarized as follows:

Question: In your opinion, do clients prefer homes with or without sump pump systems or is it not a concern?

Realtor 1 - "Water problems are a concern of purchasers. In certain areas, sump pump systems are an item purchasers ask about."

Realtor 2 - "Not a major concern. People do like it."

Question: Do Real Estate Agents inform clients if a home has a sump pump system?

Realtor 1 - "Yes, if a system is in the home the realtor should point this out to purchasers."

Realtor 2 - "Yes, most realtors do upon inspection."

Question: Is there any difference in saleability when considering homes with and without sump pump systems?

Realtor 1 - "Not presently."

Realtor 2 - "Not really."

"Sometimes people see them and they think there is a reason for concern."

5. PROVINCIAL AND MUNICIPAL OFFICIALS

5.1 Alberta Labour General Safety Services Division
Plumbing and Gas Safety Services Branch

"The Alberta and Canadian Plumbing Codes do not refer to the installation of sump pump systems."

The Alberta Building Standards Branch indicated that the Alberta Building Code does not require the installation of weeping tile. The decision to install weeping tile is left up to individual municipalities that would most likely consider their specific ground water conditions when deciding if foundation drainage systems were necessary.

5.2 City of Edmonton Planning and Development
Plumbing and Gas, Building Inspection Branch

This City of Edmonton official stated that the majority of complaints and inquiries the City receives regarding sump pump systems deal with their mechanical and operational reliability. For example, during the storm event in the first week of July 1990, North Edmonton experienced a power failure, which rendered all affected sump pump systems inoperable. As a result, there were many reports of basement flooding. This power failure can be identified as the cause of the flooding, not ineffective sump pump systems as is widely believed.

Since power failure during a severe storm event is not uncommon, the official indicated that a form of 12-volt battery back-up system should be developed to power the sump pump system during incidents of power failure, thus preventing or reducing the occurrence of basement flooding.

The City official believes the most simple solution to eradicate incidents of basement flooding and sump pump system discharge problems, would be to connect the foundation drainage system to the storm sewer where possible. He suggested that in new subdivisions, storm sewer service should be extended to, or should be available to, all lots.

The following are comments from the City of Edmonton official:

- The best sump pump is the submersible type costing approximately $300 to $400. The majority of homeowners who have bought these more expensive sump pumps have only done so after their original inexpensive pump had failed.

- Concern was expressed about the quality of sump water being discharged. He stated that areas of Edmonton, west of 149th street, reside upon an abundance of peat moss. Homeowners from these areas have complained of discoloured grass in the warmer months and discoloured ice buildup in winter months, at the location of sump discharge. It was stated that this discolouration may be caused by certain minerals in the groundwater or, possibly by staining from the peat.

- Bacteriological problems associated with standing water in sump pits have also raised concern due to a number of complaints of recurring allergies. It is believed that sanitary conditions of some sump pits encourages bacterial growth which may contribute to the physiological problems these homeowners are experiencing.

5.3 Strathcona County
Public Works
Building Inspections Branch

"Contractors have installed sump pumps in Strathcona County for the past five years." Since there are no relevant or applicable codes pertaining to sump pump installation, contractors choose and install sump pump systems in a manner that they believe is appropriate. As a result some contractors choose inappropriate sump pump locations. For example:

- Discharge pipes have been located between closely adjacent homes destroying grass and causing other inconveniences.

- In some cases sump pump discharge has been located on the high end of the lot (lot graded back-to-front). Therefore, water exiting the discharge pipe is required to run along the foundation walls before reaching a roadway or drainage structure. This may cause an appreciable amount of water to recirculate through the sump pump system.

The Strathcona County Building Inspector believes that the orientation of sump pits, and related systems, in private residences should be improved. For example:

- Upon reviewing existing or proposed lot grading, the sump pump system should be oriented within the home such that the location of sump pump discharge will work in conjunction with lot grading to efficiently remove water.

- The sump pit should be located near a floor drain. In the event of a mechanical or power failure overflow water from the sump pit can

exit the basement via the floor drain. It would be recommended that a form of swale or trough be constructed in the concrete slab to facilitate this flow, thus preventing any water damage that may occur if the overflow water is permitted to travel across the floor slab. The construction of a trough or swale is preferred rather than the installation an under-slab plastic pipe connecting the sump pit directly to the floor drain. It is believed that residents would remove or shut-off the sump pump and simply allow weeping tile water to enter the sanitary sewer via the under-slab connection.

The building inspector feels that contractors and the public have misconceptions in their beliefs that "all homes must have basements". The building inspector believes that basement construction should be avoided if homes are being built in an area that has an abundance of groundwater or a notoriously high water table.

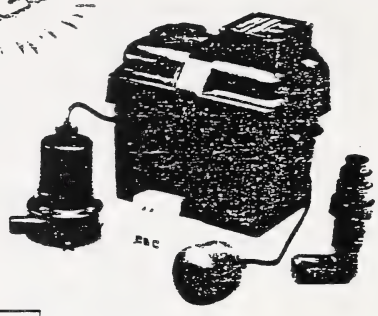
MANUFACTURERS' LITERATURE

BACK-UP PUMPS & SYSTEMS

AUTOMATIC 12 VOLT EMERGENCY SUMP PUMP SYSTEM

MODEL A2000

- Provides protection for basements
- System works when main pump doesn't
- Automatic controls keep 12 volt battery charged
- Uses standard automotive 12 volt battery
- 12 volt DC pump motor works smoothly and quietly
- Float switch operation for reliability
- Alarm sounds when pump comes on
- "State-of-the-Art" computer chip circuitry provides electronic reliability



PERFORMANCE

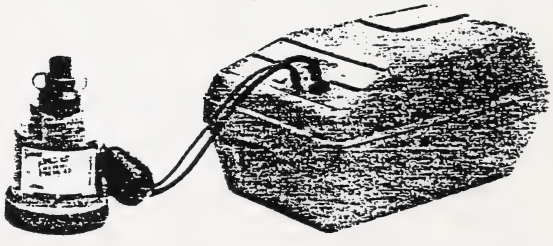
Model	Discharge Height Above Pumping Level	0'	5'	10'	15'	20'
A2000	Gallons per Minute	25	20	12	8	3

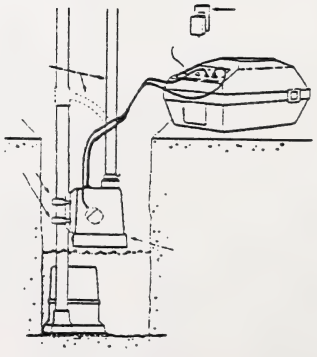
ACE-IN-THE-HOLE

THE "ORIGINAL" — ACCEPT NO SUBSTITUTES!

MODEL A5000

- The greatest protection for basements
- Pumps up to 26 GPM — important for most sumps
- Control panel features test/retest switch, warning alarm and signal lights
- Reliable float switch operation
- Uses any standard 12 volt automotive battery
- Battery is kept charged and automatically re-charges when pump is used
- If power goes out or the main sump pump fails, the Ace-In-The-Hole will keep the basement dry
- Year round, 24 hour protection from catastrophe





PERFORMANCE

Model	Discharge Height Above Pumping Level	0'	5'	10'	15'	20'	25'
A5000	Gallons per Minute	26	24	22	18	15	10

SAMPLE SURVEY MATERIALS

PUBLIC NOTICE

RESEARCH PROJECT TO EVALUATE SUMP PUMP SYSTEMS

Strathcona County with the support of Alberta Municipal Affairs, Housing Division, Research and Development Section, is undertaking a study into Sump Pump systems.

CH2M HILL ENGINEERING LTD., as the consultant for the project will be doing a telephone survey asking questions on Sump Pump operations commencing 1990 October 15 to 1990 October 26. Resident cooperation is requested in assisting with this research.

Residents currently with a Sump Pump System for foundation drainage are requested to be part of the survey and contact the offices of CH2M HILL ENGINEERING LTD. (488-2760) and complete the questionnaire over the phone. Calls will be received between 7:45 a.m. to 5:00 p.m. weekdays. Your cooperation in this research is needed to improve sump pump design.

CH2M HILL ENGINEERING LTD
10240 - 124 Street
Edmonton, Alberta
T5N 3W6 PH: 488-2760

Figure A1 PUBLIC NOTICE

EVALUATION OF THE PERFORMANCE AND EFFECTIVENESS OF SUMP PUMP SYSTEMS FOR HANDLING RESIDENTIAL FOUNDATION DRAINAGE

QUESTIONNAIRE

The following questions will aid in the on-going research to improve sump pump systems. Your answers are necessary in the completion of the work.

1. Questions on operating characteristics of your system.

   1a. What is the approximate running time of the pump from when it turns on to shutting off. _____ minutes

   1b. Summer-dry weather_____ times pump runs, per 24 hour day (approximate)

   Summer-wet weather _____ times pump runs per 24 hour day (approximate)

   Winter-cold-10°C and colder _____ times pump runs per 24 hour day (approximate)
   Winter-from 5°C to -10°C _____ times pump runs per 24 hour day (approximate)

   1c. Has your sump pump ever run for an unusual amount and if so what was the weather condition?

   _____

   _____

   _____

2. List any maintenance, repairs and modifications which you have made to your sump pump system.

   2a. Maintenance _____

   2b. Repairs _____

   2c. Modifications _____

Figure A2 QUESTIONNAIRE

3. List and describe the types of maintenance and repairs with their related costs.

Description	Cost
3a_____	_____
3b _____	_____
3c _____	_____
3d _____	_____
3e _____	_____

4. Does the sump pump have an effect on the livability of your home?
Example: Would you choose a home with a sump pump system if you had to move?

5. List any problems you have with your sump pump system.

_____

_____

_____

6. Are you aware of the function and need for a sump pump system? Yes ___ No___
If yes briefly describe your interpetation of the need for a sump pump system.

_____

_____

_____

CH2M HILL ENGINEERING LTD.

1991 November 27

EDM23241.A0.72

Little Giant Pump Company
P.O. Box 12010
3810 N. Tulsa
Oklahoma City, Oklahoma
73112

Dear Sir:

CH2M HILL ENGINEERING LTD., in conjunction with Alberta Municipal Affairs, Housing Division, Research and Development section, is undertaking a study into residential sump pump systems. The study includes carrying out investigations on the performance of residential sump pump systems installed in the Province of Alberta. As the consultant for this study, CH2M HILL ENGINEERING LTD. will make recommendations on sump pump systems, which may include guidelines on their design, installation and operation.

The data gathering process of this study involves contacting individuals within the manufacturing, municipal, construction, and residential sectors to obtain facts and perspectives on the design and operation of residential sump pump systems.

Enclosed is a brief questionnaire, and a summarized copy of specifications from the City of Winnipeg, Province of Manitoba, Canada, dealing with sump pump installation. Please complete the questionnaire as fully as possible and, comment on the specifications deleting or adding any information you feel appropriate. In addition, please send me technical data on all series of Little Giant Residential Sump Pumps (ie. pump performance curves, dimensions, capacity, etc.) as soon as possible. I will be contacting you on 1990 December 5 to briefly discuss your opinions regarding the questionnaire and specifications.

Figure A3

Your assistance will greatly facilitate ongoing research into residential sump pump systems in the Province of Alberta. If you have any questions or immediate suggestions, please contact me at your convenience. Phone: (403)488-2760.

Sincerely,

Alan J. Merz
Technician

AJM:os

Enclosure

MULTI-FAMILY SITE INVESTIGATION

MULTI-FAMILY DEVELOPEMENT
EVALUATION OF SUMP PUMP PERFORMANCE

FIELD INVESTIGATION REPORT

PROJECT NO.: EDM23243.A0

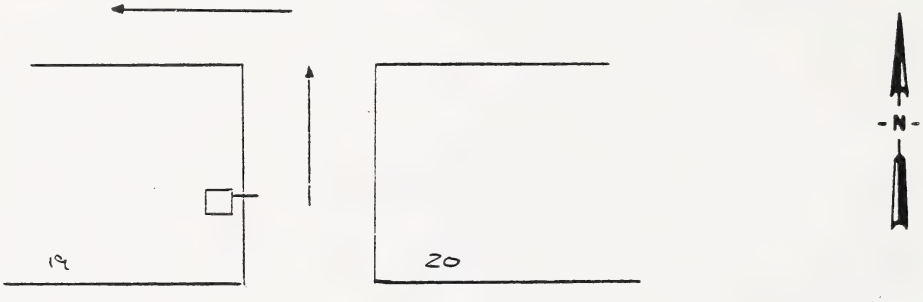
PERSONNEL: MERZ
WONG

DATE: 91/01/25

SITE ADDRESS: HOME 27 CARRINGTON WEST

UNIT NO. FROM PLAN: 20

1. ORIENTATION OF SUMP PIT WITHIN RESIDENCE; DIAGRAM:



2. MANUFACTURER/MODEL OF SUMP PUMP:
(2) HYDROMATIC SW25A1 6-89
115V 60HZ 8.0A

3. EVIDENCE OF PHYSICAL DAMAGE:
- SOME RUST
- VERY DIRTY - CONSISTS WITH SAND SILT & CLAY
- CONCRETE SAND UNDER FLOOR SLAB "WASHING" INTO SUMP PIT.

4. INLET PIPE DIA.:
N/A

5. OUTLET PIPE DIA.:
≅ 50mm

PAGE 1

Figure A4

6. CONSTRUCTION OF SUMP PIT:

- PRESSURE TREATED OSB WATERPROOF PLYWOOD - NO BOTTOM

7. EVIDENCE OF BACTERIOLOGICAL PROBLEMS:

- STAGNANT SEWAGE PRESENT
- WATER EXTREMELY DISCOLOURED - BROWN / YELLOW
- WHITE CLOUDY SUBSTANCE SUSPENDED IN WATER

8. SUMP PUMP PERFORMANCE TEST

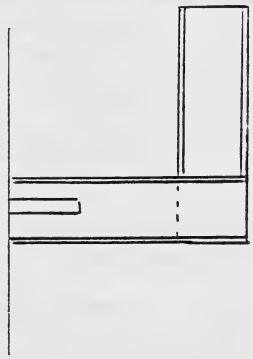
INTERIOR	
DIMENSIONS	
HEIGHT	690 mm
WIDTH	540 mm
DEPTH	540 mm
VOLUME	200L
DISCHARGE	
TIME	35 SEC
RATE	

EXTERIOR	
DISCHARGE	
VOLUME	16.37 L
TIME	7 SEC
RATE	2.34 L/S

82 L AVAILABLE STORAGE

9. TYPE OF DISCHARGE STRUCTURE; DIAGRAM:

- 50mm DISCHARGE PIPE EXTENDING FROM EAST SIDE OF UNIT 19
- DISCHARGE ONTO CEMENT SPLASH PAD



10. IDENTIFY BY VISUAL INSPECTION APPROXIMATE DISCHARGE:

DISCHARGE	
DRY	
LOW	
MEDIUM	
HIGH	X

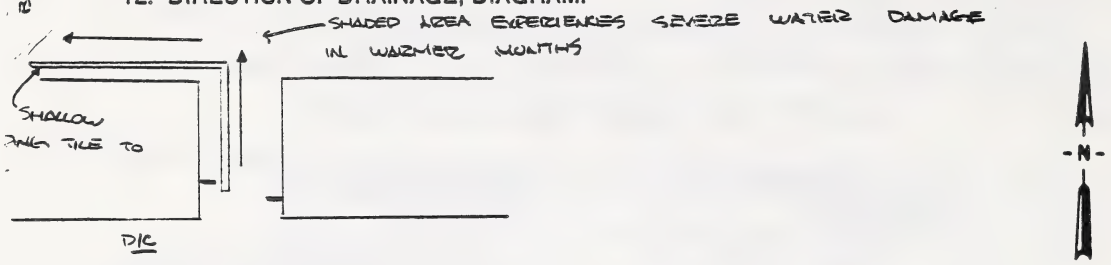
CH2MHILL

BEHIND HOME 34

11. EVIDENCE OF DAMAGE OR HAZARDOUS CONDITION FROM DISCHARGE:

- EXTREME DAMAGE TO SOD → VERY MUDDY AND WET IN WARMER MONTHS
- EXCESSIVE ICE BUILD-UP

12. DIRECTION OF DRAINAGE; DIAGRAM:

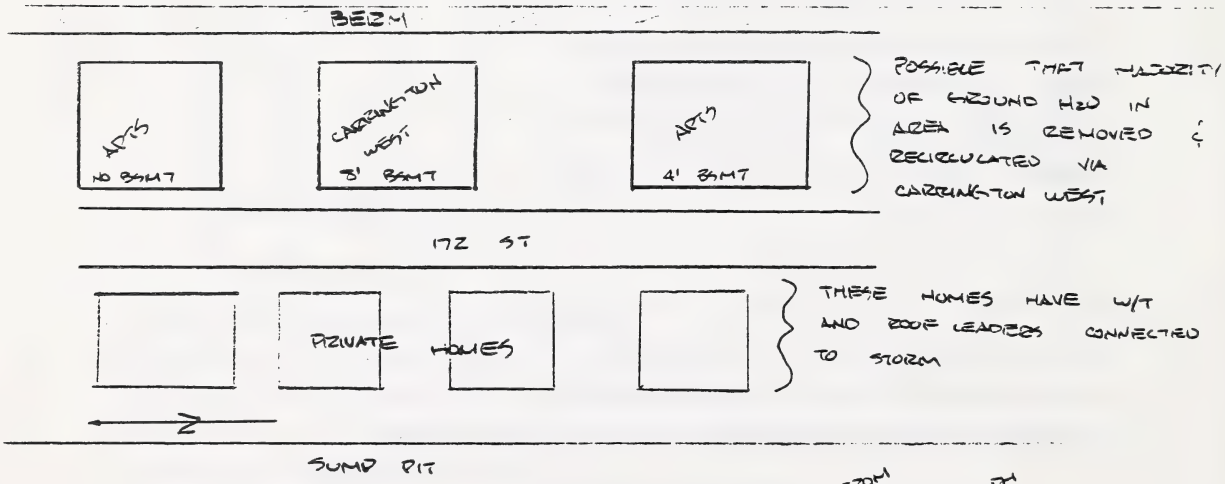


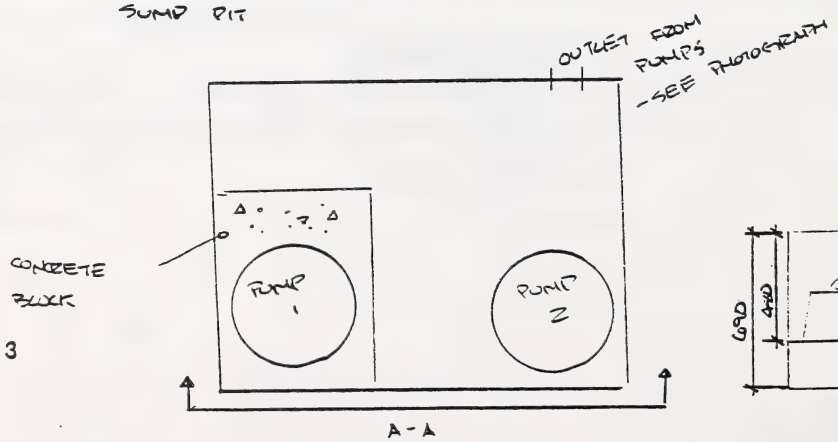
DIC

DRY = 2 X PER HOUR

WET = EVERY 10 MINUTES

NOTE - SOME HOMES (CAN BE IDENTIFIED BY DRY DIC) HAVE CONNECTED SUMP PUMP TO SANITARY SEWER. HOMEOWNERS DID THE CONVERSIONS THEMSELVES





MULTI-FAMILY DEVELOPEMENT
EVALUATION OF SUMP PUMP PERFORMANCE

FIELD INVESTIGATION REPORT

PROJECT NO.: EDM23243.A0

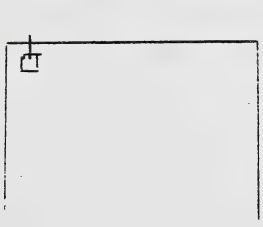
PERSONNEL: MEZZ
WOLK

DATE: 91/01/25

SITE ADDRESS: 15440 -54 ST 402-5201 WEST - SIDE ST. ZONITH

UNIT NO. FROM PLAN 1

1. ORIENTATION OF SUMP PIT WITHIN RESIDENCE; DIAGRAM:



2. MANUFACTURER/MODEL OF SUMP PUMP:
HYDROMATIC SW25

3. EVIDENCE OF PHYSICAL DAMAGE:
- SOME RUST
- PUMP SLIGHTLY DIRTY (MUD ETC.

4. INLET PIPE DIA.: (TO SUMP)
2) 50mm

5. OUTLET PIPE DIA.:
50mm

PAGE 1

6. CONSTRUCTION OF SUMP PIT:

- PRESSURE TREATED OR WATERPROOF PLYWOOD BOX NO BOTTOM
- PLYWOOD LID 12 VENT HOLES 30 mm Ø EACH
- WASH ROCK ON BOTTOM 10 mm CRUSH

7. EVIDENCE OF BACTERIOLOGICAL PROBLEMS:

NONE - SUMP VERY DRY SOME DEBRIS - WOOD
- BRICK
- STEEL
- CONSTRUCTION MATERIAL (WASTE)

8. SUMP PUMP PERFORMANCE TEST

INTERIOR	
DIMENSIONS	
HEIGHT	980 mm
WIDTH	620 mm
DEPTH	600 mm
VOLUME	277L
DISCHARGE	
TIME	50 sec
RATE	2.4 L/s

EXTERIOR	
DISCHARGE	
VOLUME	
TIME	
RATE	

/120 L AVAILABLE STORAGE

HEIGHT OF WATER LINE 260 mm FROM BOTTOM

9. TYPE OF DISCHARGE STRUCTURE; DIAGRAM:

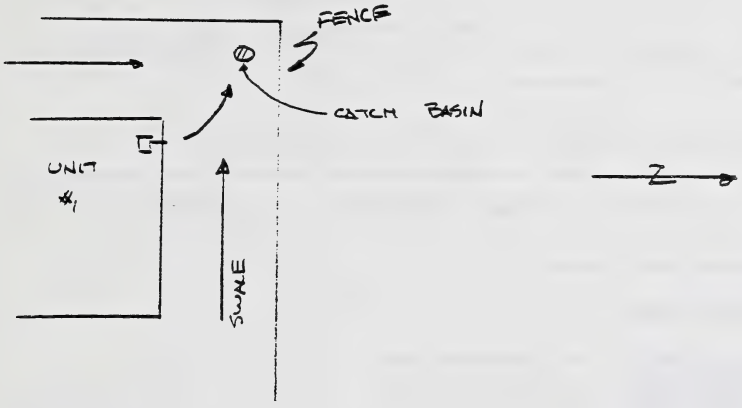
- PLASTIC 50mm PIPE TO
- POLLEN PAD

10. IDENTIFY BY VISUAL INSPECTION APPROXIMATE DISCHARGE:

DISCHARGE	
DRY	X
LOW	
MEDIUM	
HIGH	

11. EVIDENCE OF DAMAGE OR HAZARDOUS CONDITION FROM DISCHARGE:
NONE

12. DIRECTION OF DRAINAGE; DIAGRAM:



MULTI–FAMILY DEVELOPEMENT
EVALUATION OF SUMP PUMP PERFORMANCE

FIELD INVESTIGATION REPORT

PROJECT NO.: EDM23243.A0

PERSONNEL: MIEZZ
WONG

DATE: 91/01/25

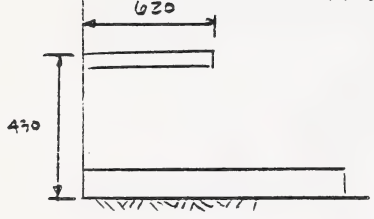
SITE ADDRESS: CARRINGTON WEST

UNIT NO. FROM PLAN:	6

TYPE OF DISCHARGE STRUCTURE:

OUTLET DIA.:	50mm
OUTLET MATERIAL:	PLASTIC

DIAGRAM NTS



NOTES:

DISCHARGE TO CATCHBASIN 2
SPLASH PAD

IDENTIFY BY VISUAL INSPECTION APPROXIMATE DISCHARGE:

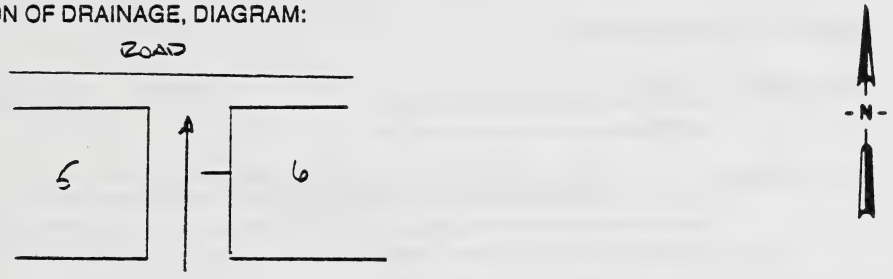
DISCHARGE	
DRY	✓
LOW	
MEDIUM	
HIGH	

PAGE 1

EVIDENCE OF DAMAGE OR HAZARDOUS CONDITION FROM DISCHARGE:

- NONE APPARENT
- POSSIBLE MUDDY & WET SOIL IN WARM MONTHS

DIRECTION OF DRAINAGE, DIAGRAM:



COMMENTS:

POSSIBLE CONNECTION TO SANITARY SEWERS

MULTI-FAMILY DEVELOPEMENT
EVALUATION OF SUMP PUMP PERFORMANCE

FIELD INVESTIGATION REPORT

PROJECT NO.: EDM23243.A0

PERSONNEL: MEZZ
WONG

DATE: 91/01/24

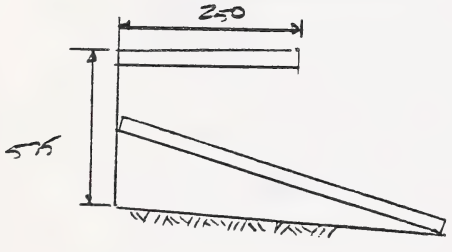
SITE ADDRESS: AMMENITY BLDG. CARRINGTON WEST

UNIT NO. FROM PLAN:	N/A

TYPE OF DISCHARGE STRUCTURE:

OUTLET DIA.:	50mm
OUTLET MATERIAL:	PLASTIC

DIAGRAM N.T.S.



NOTES:

DISCHARGE TO RECTANGULAR SPLASH PAD

IDENTIFY BY VISUAL INSPECTION APPROXIMATE DISCHARGE:

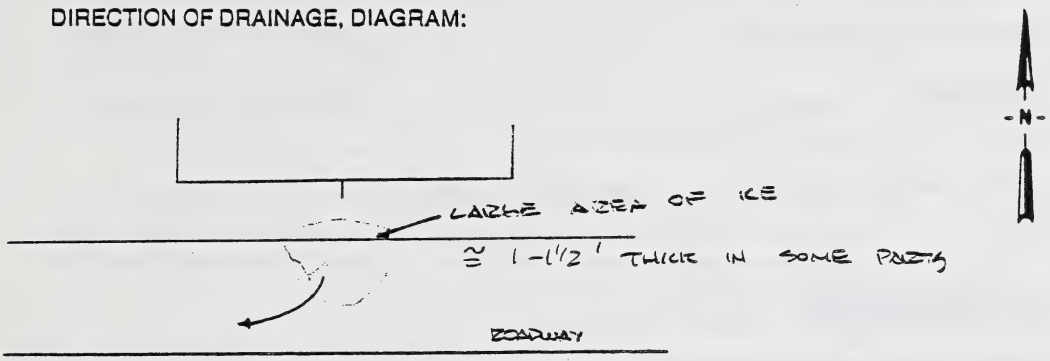
DISCHARGE	
DRY	
LOW	
MEDIUM	
HIGH	✓

PAGE 1

EVIDENCE OF DAMAGE OR HAZARDOUS CONDITION FROM DISCHARGE:

EXTREME ICE BUILD-UP ON ROADWAY AND CRACKS

DIRECTION OF DRAINAGE, DIAGRAM:



COMMENTS:

MULTI-FAMILY DEVELOPEMENT
EVALUATION OF SUMP PUMP PERFORMANCE

FIELD INVESTIGATION REPORT

PROJECT NO.: EDM23243.A0

PERSONNEL: MEZZ
WONG

DATE: 9/10/25

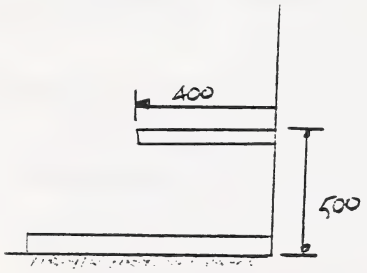
SITE ADDRESS: HOME 17 CARRINGTON WEST

UNIT NO. FROM PLAN:	15

TYPE OF DISCHARGE STRUCTURE:

OUTLET DIA.:	50mm
OUTLET MATERIAL:	PLASTIC

DIAGRAM



NOTES:

DISCHARGE TO RECTANGULAR
STRAW PAD

IDENTIFY BY VISUAL INSPECTION APPROXIMATE DISCHARGE:

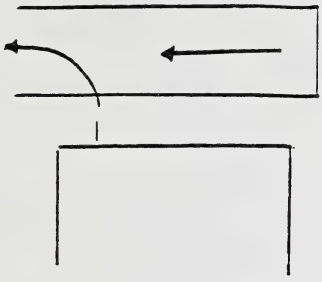
DISCHARGE	
DRY	✓
LOW	
MEDIUM	
HIGH	

PAGE 1

EVIDENCE OF DAMAGE OR HAZARDOUS CONDITION FROM DISCHARGE:

NONE

DIRECTION OF DRAINAGE, DIAGRAM:



COMMENTS:

THIS SERIES OF UNITS HAS S/P CONNECTED TO SANITARY SEWER - CONFIRMED

APPENDIX B

TESTING PROGRAM RESULTS

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APPENDIX B
TESTING PROGRAM RESULTS

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   1.2 September 5, 1991 Results
   - Small Sump, Discharge at Wall,
   Saturated Site Condition B-9
   1.3 September 6, 1991 Results
   - Large Sump, Splash Pad B-17
   1.4 September 7, 1991 Results
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   1.5 Related Testing B-30

1. TEST RESULTS

This section of Appendix B presents the monitored results of the field testing program. Analysis of the tests is presented in Section 7.0, Testing Program Results and Analysis.

The results of the tests are presented in the following sequence for September 3, 5, 6, and 7, July 15, 16, and August 26, and 28, 1991.

Inflow/Intensity Figure (Typical for each simulation)

This figure presents the lot characteristics in the top right corner, the rainfall event in the top left corner, and the foundation drain inflow response as measured by sump level recorders.

Recycled Inflow (Typical)

This figure is a compiled graph to illustrate sump water discharge that is recycled back to the foundation drain. The graph was derived by subtracting inflow values of tests where the sump discharge water was conveyed offsite, from the inflow values of the noted tests, where the discharge water remained onsite.

Pump Cycle Time (Typical)

The Pump Cycle Time graph is the running time recorded by the on/off sensor in relation to test time.

Cycle Time (Typical)

The Cycle Time charts tabulate sump running time compared to test time. The time the simulation began is 00:00:00. This chart relates peak pump cycle time to peaks in the hyetographs.

Piezometer (Typical)

The piezometer charts present groundwater fluctuations relative to the top of footing (weeping tile) for the piezometers equipped with water level recorders. The maximum level is the maximum groundwater fluctuation during the simulated test.

1.1 September 3, 1991 Results

Small Sump, Discharge at Wall

The site configuration for this simulation was a single lot. The front-yard sump was used. The test went well and no problems were encountered.

Simulation Data Summary

Simulated event	4 hours, 1:5
Test started at	9:40 a.m.
Weather	Sunny, 23° C, windy
Total volume of water applied	22.04 m^3
Maximum inflow	0.9 L/s
Maximum recycled	0.4 L/s
Maximum pump cycle time	48 sec.

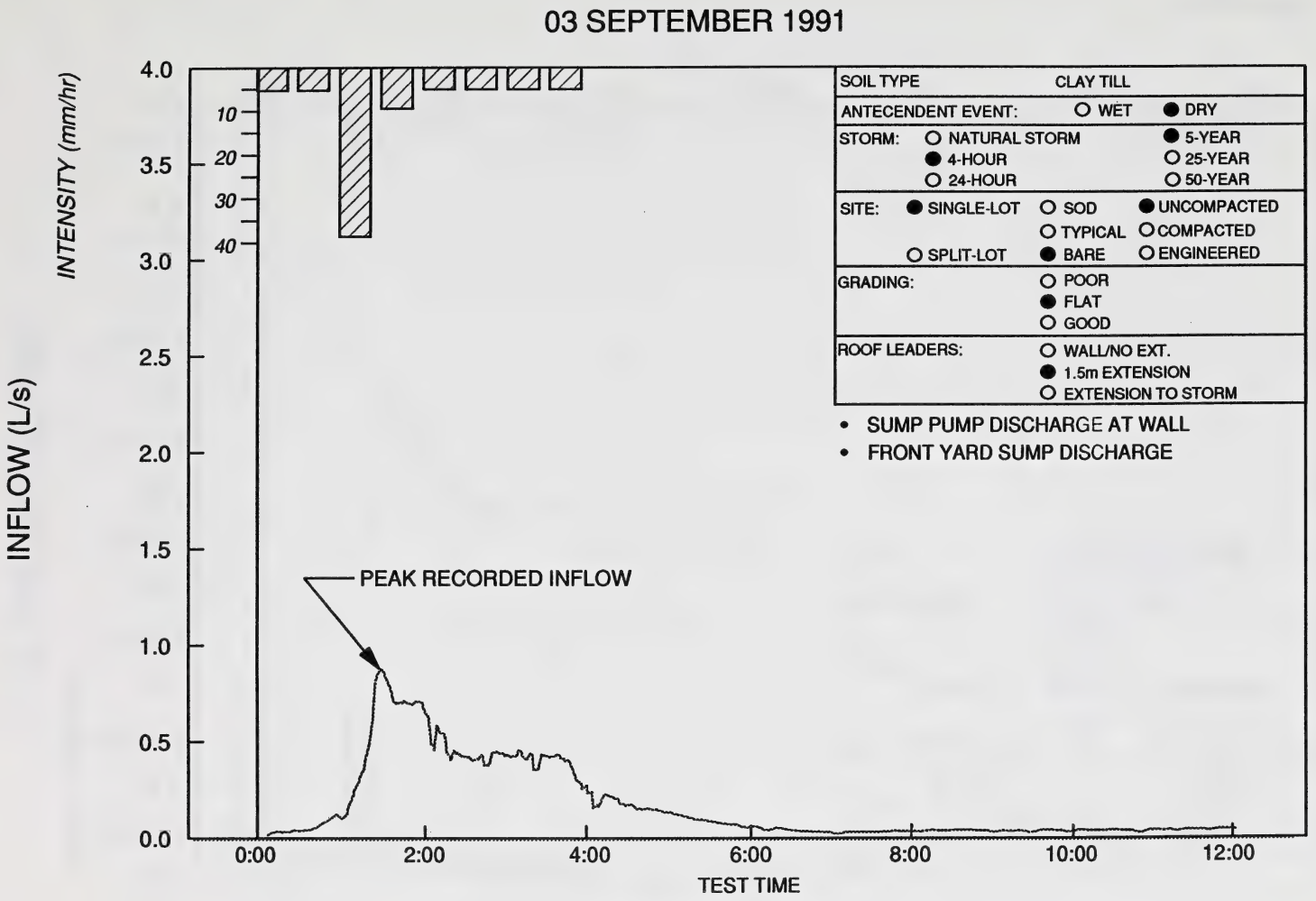
03 SEPTEMBER 1991
INTENSITY (mm/hr)
10
20
30
40
INFLOW (L/s)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
PEAK RECORDED INFLOW
SOIL TYPE CLAY TILL
ANTECEDENT EVENT: O WET ● DRY
STORM: O NATURAL STORM ● 5-YEAR
● 4-HOUR O 25-YEAR
O 24-HOUR O 50-YEAR
SITE: ● SINGLE-LOT O SOD ● UNCOMPACTED
O TYPICAL O COMPACTED
O SPLIT-LOT ● BARE O ENGINEERED
GRADING: O POOR
● FLAT
O GOOD
ROOF LEADERS: O WALL/NO EXT.
● 1.5m EXTENSION
O EXTENSION TO STORM
• SUMP PUMP DISCHARGE AT WALL
• FRONT YARD SUMP DISCHARGE

Figure B1

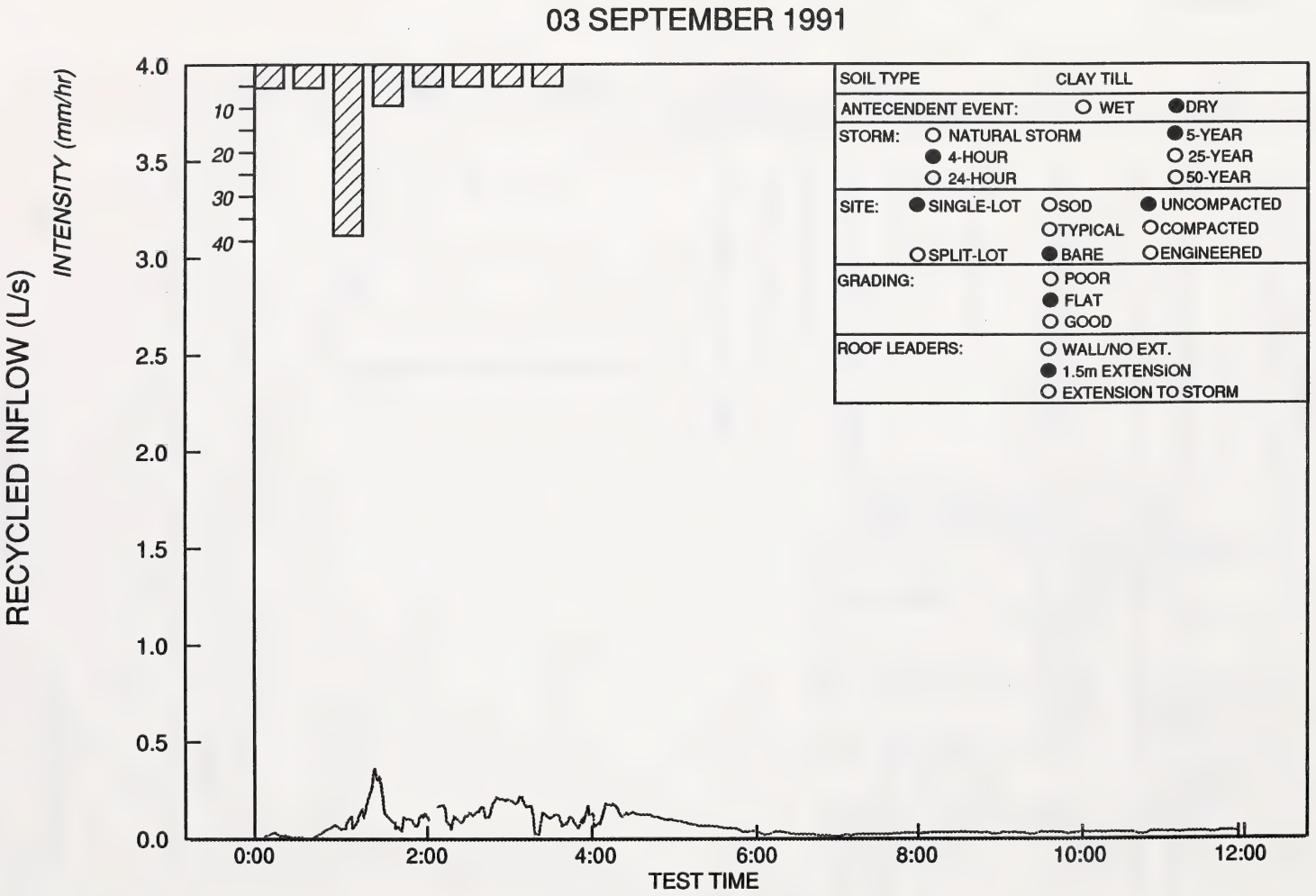
03 SEPTEMBER 1991
RECYCLED INFLOW (L/s)
INTENSITY (mm/hr)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10
20
30
40
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: O WET ● DRY
STORM: O NATURAL STORM ● 4-HOUR O 24-HOUR ● 5-YEAR O 25-YEAR O 50-YEAR
SITE: ● SINGLE-LOT O SPLIT-LOT O SOD O TYPICAL ● BARE ● UNCOMPACTED O COMPACTED O ENGINEERED
GRADING: O POOR ● FLAT O GOOD
ROOF LEADERS: O WALL/NO EXT. ● 1.5m EXTENSION O EXTENSION TO STORM

Figure B2

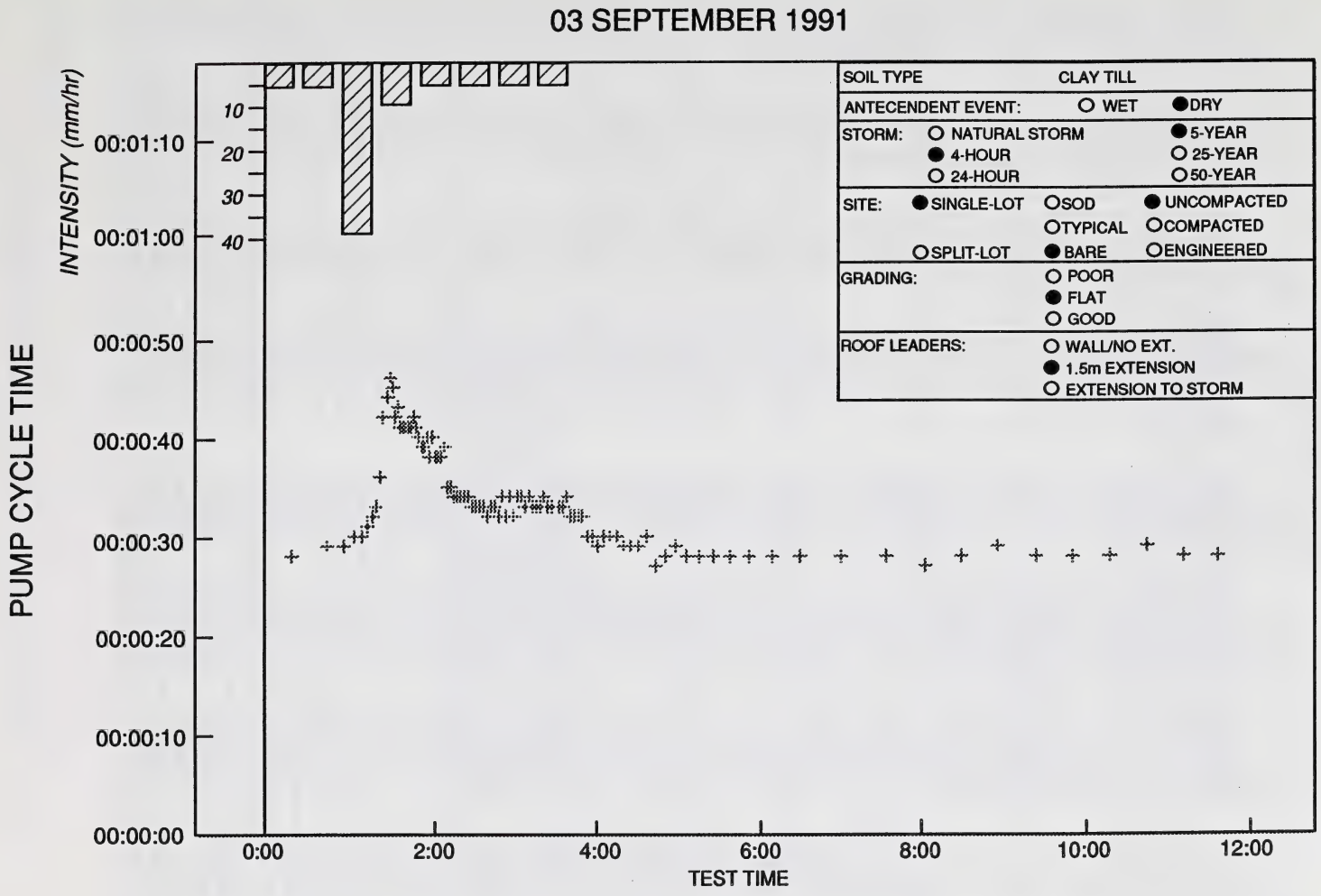
03 SEPTEMBER 1991
PUMP CYCLE TIME
INTENSITY (mm/hr)
10
20
30
40
00:01:10
00:01:00
00:00:50
00:00:40
00:00:30
00:00:20
00:00:10
00:00:00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: O WET ● DRY
STORM: O NATURAL STORM ● 4-HOUR O 24-HOUR ● 5-YEAR O 25-YEAR O 50-YEAR
SITE: ● SINGLE-LOT O SPLIT-LOT O SOD O TYPICAL ● BARE ● UNCOMPACTED O COMPACTED O ENGINEERED
GRADING: O POOR ● FLAT O GOOD
ROOF LEADERS: O WALL/NO EXT. ● 1.5m EXTENSION O EXTENSION TO STORM

Figure B3

CYCLE TIME
FRONT PUMP ONLY

REAL DATE	REAL TIME	CYCLE TIME	TEST TIME
09/03/91	10:00:24	00:00:28	00:20:24
09/03/91	10:26:16	00:00:29	00:46:16
09/03/91	10:38:39	00:00:29	00:58:39
09/03/91	10:46:29	00:00:30	01:06:29
09/03/91	10:51:58	00:00:30	01:11:58
09/03/91	10:56:13	00:00:31	01:16:13
09/03/91	10:59:40	00:00:32	01:19:40
09/03/91	11:02:47	00:00:33	01:22:47
09/03/91	11:05:28	00:00:36	01:25:28
09/03/91	11:07:25	00:00:42	01:27:25
09/03/91	11:11:07	00:00:44	01:31:07
09/03/91	11:12:54	00:00:46	01:32:54
09/03/91	11:14:44	00:00:45	01:34:44
09/03/91	11:16:37	00:00:42	01:36:37
09/03/91	11:18:32	00:00:43	01:38:32
09/03/91	11:20:28	00:00:41	01:40:28
09/03/91	11:22:24	00:00:41	01:42:24
09/03/91	11:24:21	00:00:41	01:44:21
09/03/91	11:26:18	00:00:41	01:46:18
09/03/91	11:28:17	00:00:41	01:48:17
09/03/91	11:30:15	00:00:42	01:50:15
09/03/91	11:32:16	00:00:41	01:52:16
09/03/91	11:34:16	00:00:40	01:54:16
09/03/91	11:36:16	00:00:39	01:56:16
09/03/91	11:38:14	00:00:39	01:58:14
09/03/91	11:40:12	00:00:40	02:00:12
09/03/91	11:42:11	00:00:38	02:02:11
09/03/91	11:44:10	00:00:40	02:04:10
09/03/91	11:46:16	00:00:38	02:06:16
09/03/91	11:48:24	00:00:38	02:08:24
09/03/91	11:50:32	00:00:38	02:10:32
09/03/91	11:52:43	00:00:39	02:12:43
09/03/91	11:55:11	00:00:35	02:15:11
09/03/91	11:57:31	00:00:35	02:17:31
09/03/91	11:59:54	00:00:34	02:19:54
09/03/91	12:02:26	00:00:34	02:22:26
09/03/91	12:05:07	00:00:34	02:25:07
09/03/91	12:07:53	00:00:34	02:27:53
09/03/91	12:10:40	00:00:34	02:30:40
09/03/91	12:13:29	00:00:33	02:33:29
09/03/91	12:16:19	00:00:33	02:36:19
09/03/91	12:19:09	00:00:33	02:39:09
09/03/91	12:22:00	00:00:33	02:42:00
09/03/91	12:24:51	00:00:32	02:44:51
09/03/91	12:27:41	00:00:33	02:47:41
09/03/91	12:30:29	00:00:33	02:50:29
09/03/91	12:33:14	00:00:32	02:53:14
09/03/91	12:35:56	00:00:34	02:55:56
09/03/91	12:38:40	00:00:32	02:58:40
09/03/91	12:41:23	00:00:34	03:01:23

REAL DATE	REAL TIME	CYCLE TIME	TEST TIME
09/03/91	12:44:10	00:00:32	03:04:10
09/03/91	12:46:56	00:00:34	03:06:56
09/03/91	12:49:44	00:00:34	03:09:44
09/03/91	12:52:32	00:00:33	03:12:32
09/03/91	12:55:18	00:00:34	03:15:18
09/03/91	12:58:08	00:00:33	03:18:08
09/03/91	13:00:57	00:00:33	03:20:57
09/03/91	13:03:44	00:00:33	03:23:44
09/03/91	13:06:31	00:00:34	03:26:31
09/03/91	13:09:19	00:00:33	03:29:19
09/03/91	13:12:06	00:00:33	03:32:06
09/03/91	13:17:42	00:00:33	03:37:42
09/03/91	13:20:31	00:00:33	03:40:31
09/03/91	13:23:19	00:00:34	03:43:19
09/03/91	13:26:08	00:00:32	03:46:08
09/03/91	13:28:58	00:00:32	03:48:58
09/03/91	13:31:56	00:00:32	03:51:56
09/03/91	13:35:06	00:00:32	03:55:06
09/03/91	13:38:28	00:00:30	03:58:28
09/03/91	13:42:05	00:00:30	04:02:05
09/03/91	13:46:10	00:00:29	04:06:10
09/03/91	13:50:33	00:00:30	04:10:33
09/03/91	13:55:11	00:00:30	04:15:11
09/03/91	13:59:57	00:00:30	04:19:57
09/03/91	14:04:59	00:00:29	04:24:59
09/03/91	14:10:15	00:00:29	04:30:15
09/03/91	14:15:56	00:00:29	04:35:56
09/03/91	14:21:56	00:00:30	04:41:56
09/03/91	14:28:35	00:00:27	04:48:35
09/03/91	14:35:37	00:00:28	04:55:37
09/03/91	14:43:06	00:00:29	05:03:06
09/03/91	14:51:00	00:00:28	05:11:00
09/03/91	15:10:39	00:00:28	05:30:39
09/03/91	15:22:51	00:00:28	05:42:51
09/03/91	15:37:06	00:00:28	05:57:06
09/03/91	15:54:03	00:00:28	06:14:03
09/03/91	16:14:46	00:00:28	06:34:46
09/03/91	16:45:11	00:00:28	07:05:11
09/03/91	17:18:40	00:00:28	07:38:40
09/03/91	17:47:38	00:00:27	08:07:38
09/03/91	18:14:00	00:00:28	08:34:00
09/03/91	18:40:47	00:00:29	09:00:47
09/03/91	19:08:48	00:00:28	09:28:48
09/03/91	19:35:46	00:00:28	09:55:46
09/03/91	20:02:39	00:00:28	10:22:39
09/03/91	20:29:24	00:00:29	10:49:24
09/03/91	20:55:59	00:00:28	11:15:59
09/03/91	21:21:06	00:00:28	11:41:06
09/03/91	21:44:14	00:00:29	12:04:14
09/03/91	22:09:17	00:00:28	12:29:17

Figure B4

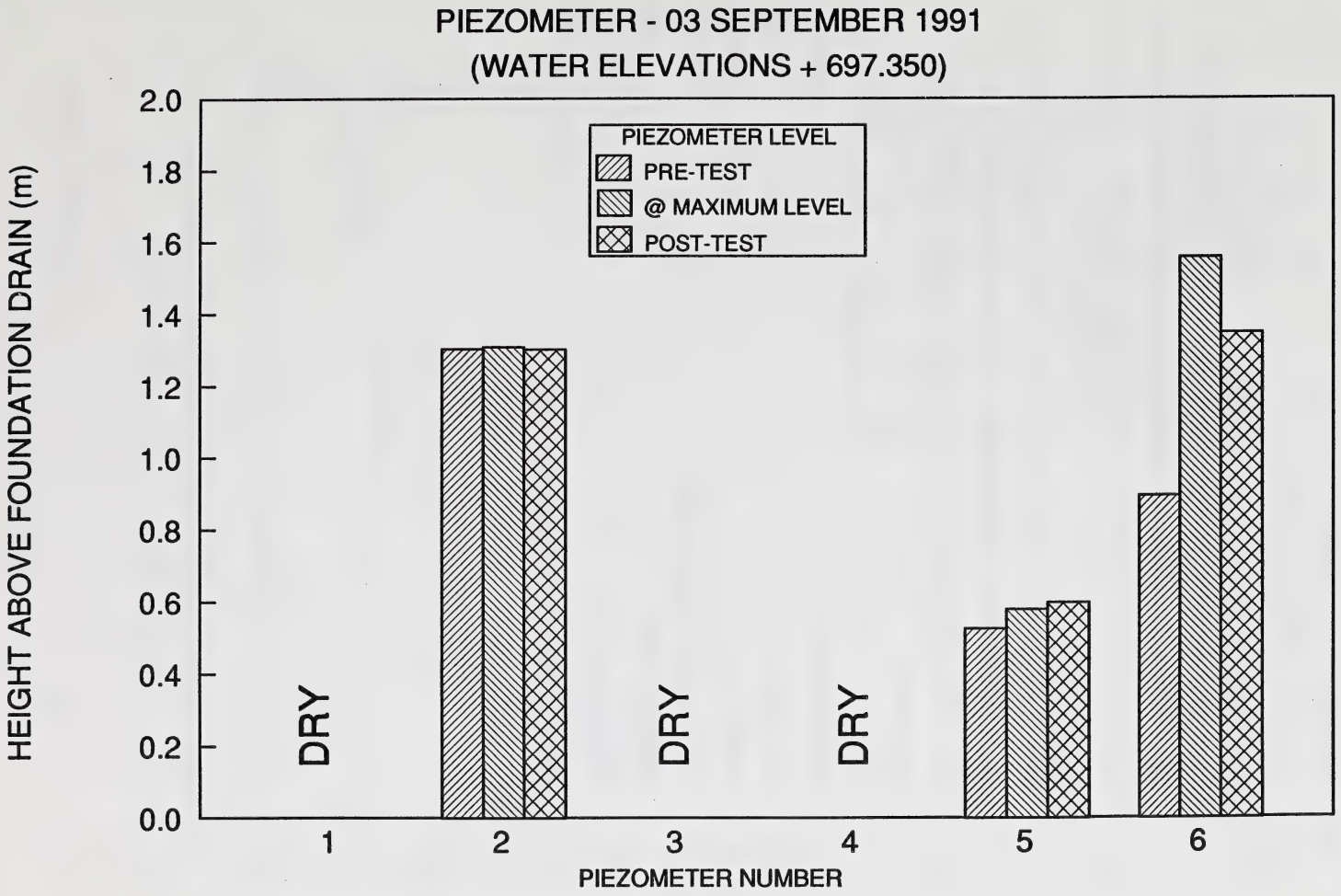
PIEZOMETER - 03 SEPTEMBER 1991
(WATER ELEVATIONS + 697.350)
HEIGHT ABOVE FOUNDATION DRAIN (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
PIEZOMETER LEVEL
PRE-TEST
@ MAXIMUM LEVEL
POST-TEST
DRY
DRY
DRY
1
2
3
4
5
6
PIEZOMETER NUMBER

Figure B5

1.2 September 5, 1991 Results

Small Sump, Discharge at Wall

The site configuration was the same as for the test on September 3, 1991, except during this simulation the site was wet and the uncompacted backfill zone had settled. No problems were encountered during testing.

The items of note for this simulation are the amount of recycled inflow and pump running times of approximately 2 to 5 min, reaching as high as 31 min. These effects are reflected in the groundwater fluctuations of piezometer 6.

Simulated event	4 hours, 1:5
Test started at	9:40 a.m.
Weather	Sunny, 23° C, windy
Total volume of water applied	22.04 m^3
Maximum inflow	2.7 L/s
Maximum recycled	2.4 L/s
Maximum pump cycle time	31 min, 21 sec.

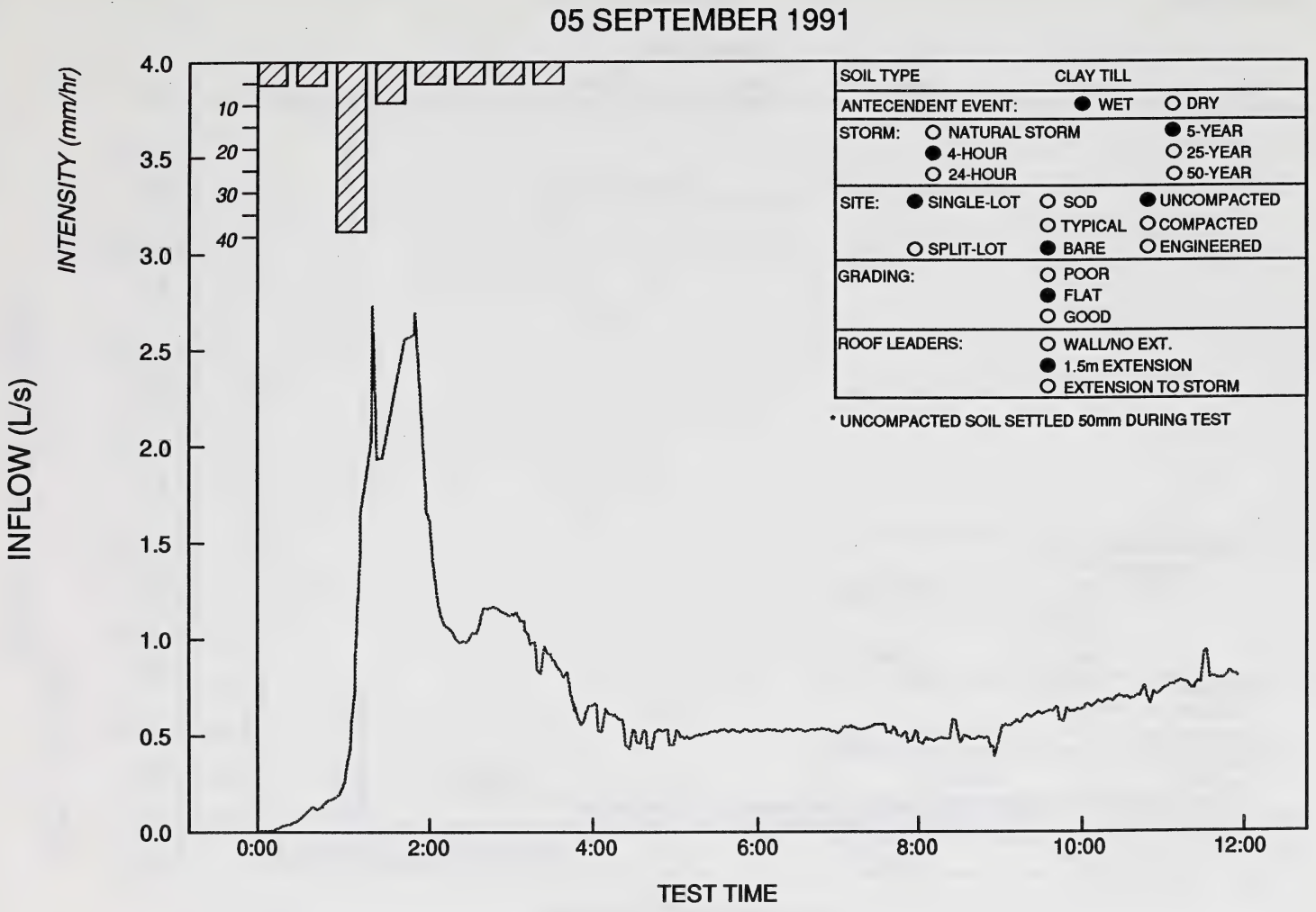
05 SEPTEMBER 1991
INTENSITY (mm/hr)
10
20
30
40
INFLOW (L/s)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 5-YEAR
● 4-HOUR ○ 25-YEAR
○ 24-HOUR ○ 50-YEAR
SITE: ● SINGLE-LOT ○ SOD ● UNCOMPACTED
○ TYPICAL ○ COMPACTED
○ SPLIT-LOT ● BARE ○ ENGINEERED
GRADING: ○ POOR
● FLAT
○ GOOD
ROOF LEADERS: ○ WALL/NO EXT.
● 1.5m EXTENSION
○ EXTENSION TO STORM
* UNCOMPACTED SOIL SETTLED 50mm DURING TEST

Figure B6

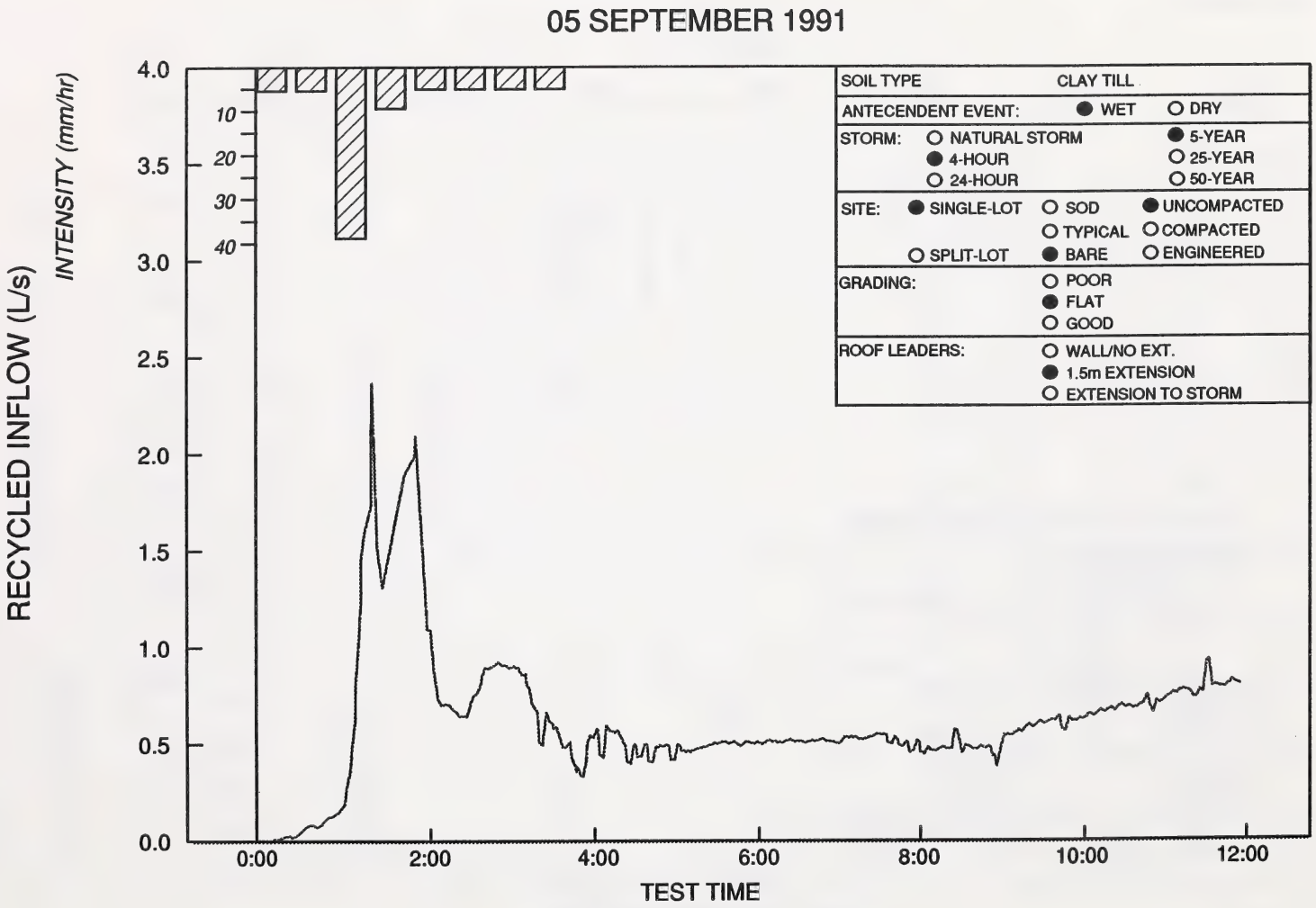
05 SEPTEMBER 1991
RECYCLED INFLOW (L/s)
INTENSITY (mm/hr)
10
20
30
40
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 5-YEAR
● 4-HOUR ○ 25-YEAR
○ 24-HOUR ○ 50-YEAR
SITE: ● SINGLE-LOT ○ SOD ● UNCOMPACTED
○ TYPICAL ○ COMPACTED
○ SPLIT-LOT ● BARE ○ ENGINEERED
GRADING: ○ POOR
● FLAT
○ GOOD
ROOF LEADERS: ○ WALL/NO EXT.
● 1.5m EXTENSION
○ EXTENSION TO STORM

Figure B7

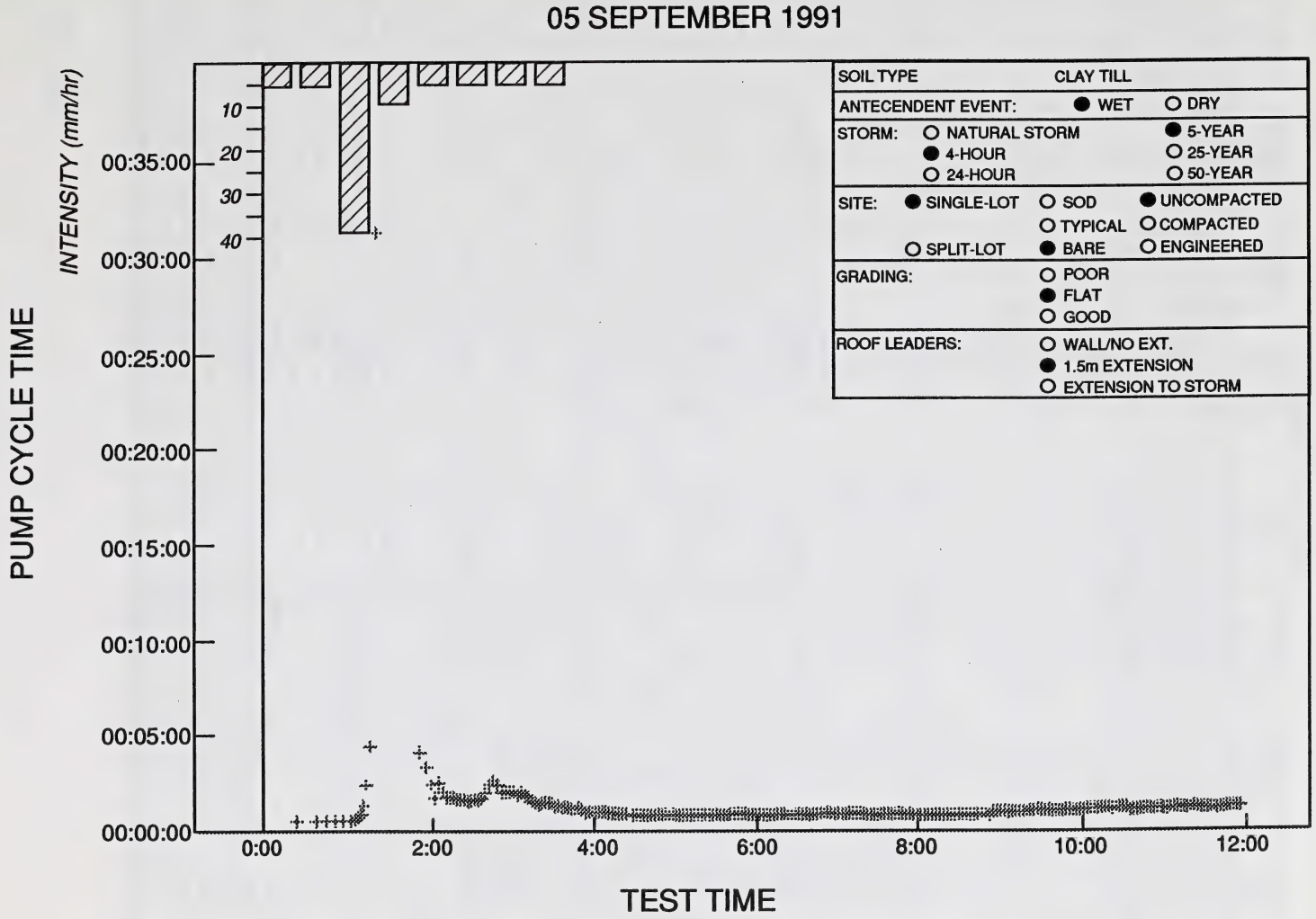
05 SEPTEMBER 1991
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 5-YEAR
● 4-HOUR ○ 25-YEAR
○ 24-HOUR ○ 50-YEAR
SITE: ● SINGLE-LOT ○ SOD ● UNCOMPACTED
○ TYPICAL ○ COMPACTED
○ SPLIT-LOT ● BARE ○ ENGINEERED
GRADING: ○ POOR
● FLAT
○ GOOD
ROOF LEADERS: ○ WALL/NO EXT.
● 1.5m EXTENSION
○ EXTENSION TO STORM
INTENSITY (mm/hr)
10
20
30
40
PUMP CYCLE TIME
00:35:00
00:30:00
00:25:00
00:20:00
00:15:00
00:10:00
00:05:00
00:00:00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME

Figure B8

CYCLE TIME
FRONT PUMP ONLY

REAL DATE	REAL TIME	CYCLE TIME	TEST TIME
09/05/91	10:05:15	00:00:29	00:25:15
09/05/91	10:19:43	00:00:30	00:39:43
09/05/91	10:27:02	00:00:31	00:47:02
09/05/91	10:33:29	00:00:31	00:53:29
09/05/91	10:39:36	00:00:31	00:59:36
09/05/91	10:44:58	00:00:31	01:04:58
09/05/91	10:48:37	00:00:36	01:08:37
09/05/91	10:50:50	00:00:43	01:10:50
09/05/91	10:52:44	00:00:52	01:12:44
09/05/91	10:54:25	00:01:18	01:14:25
09/05/91	10:56:18	00:02:24	01:16:18
09/05/91	10:59:13	00:04:25	01:19:13
09/05/91	11:04:05	00:31:21	01:24:05
09/05/91	11:35:54	00:04:07	01:55:54
09/05/91	11:40:29	00:03:21	02:00:29
09/05/91	11:44:22	00:02:25	02:04:22
09/05/91	11:47:20	00:01:43	02:07:20
09/05/91	11:49:46	00:02:31	02:09:46
09/05/91	11:53:03	00:02:01	02:13:03
09/05/91	11:55:54	00:01:46	02:15:54
09/05/91	11:58:34	00:01:46	02:18:34
09/05/91	12:01:11	00:01:45	02:21:11
09/05/91	12:03:49	00:01:39	02:23:49
09/05/91	12:06:24	00:01:38	02:26:24
09/05/91	12:09:00	00:01:38	02:29:00
09/05/91	12:11:35	00:01:32	02:31:35
09/05/91	12:14:02	00:01:33	02:34:02
09/05/91	12:16:30	00:01:40	02:36:30
09/05/91	12:19:05	00:01:36	02:39:05
09/05/91	12:21:34	00:01:42	02:41:34
09/05/91	12:24:09	00:02:00	02:44:09
09/05/91	12:26:59	00:02:25	02:46:59
09/05/91	12:30:11	00:02:37	02:50:11
09/05/91	12:33:36	00:02:24	02:53:36
09/05/91	12:36:49	00:02:00	02:56:49
09/05/91	12:39:38	00:02:01	02:59:38
09/05/91	12:42:29	00:02:03	03:02:29
09/05/91	12:45:22	00:02:04	03:05:22
09/05/91	12:48:16	00:01:52	03:08:16
09/05/91	12:50:58	00:02:00	03:10:58
09/05/91	12:53:48	00:01:50	03:13:48
09/05/91	12:56:30	00:01:44	03:16:30
09/05/91	12:59:09	00:01:33	03:19:09
09/05/91	13:01:38	00:01:29	03:21:38
09/05/91	13:04:07	00:01:22	03:24:07
09/05/91	13:06:29	00:01:26	03:26:29
09/05/91	13:08:55	00:01:30	03:28:55
09/05/91	13:11:24	00:01:29	03:31:24
09/05/91	13:13:52	00:01:27	03:33:52
09/05/91	13:16:22	00:01:16	03:36:22

REAL DATE	REAL TIME	CYCLE TIME	TEST TIME
09/05/91	13:18:43	00:01:19	03:38:43
09/05/91	13:21:09	00:01:13	03:41:09
09/05/91	13:23:31	00:01:14	03:43:31
09/05/91	13:25:55	00:01:12	03:45:55
09/05/91	13:28:18	00:01:09	03:48:18
09/05/91	13:30:43	00:01:07	03:50:43
09/05/91	13:33:16	00:01:12	03:53:16
09/05/91	13:36:03	00:01:07	03:56:03
09/05/91	13:38:48	00:00:56	03:58:48
09/05/91	13:41:14	00:00:59	04:01:14
09/05/91	13:43:40	00:00:59	04:03:40
09/05/91	13:46:06	00:00:58	04:06:06
09/05/91	13:48:30	00:01:00	04:08:30
09/05/91	13:50:57	00:00:58	04:10:57
09/05/91	13:53:23	00:00:59	04:13:23
09/05/91	13:55:51	00:00:55	04:15:51
09/05/91	13:58:18	00:00:54	04:18:18
09/05/91	14:00:46	00:00:55	04:20:46
09/05/91	14:03:16	00:00:53	04:23:16
09/05/91	14:05:44	00:00:53	04:25:44
09/05/91	14:08:18	00:00:53	04:28:18
09/05/91	14:13:42	00:00:48	04:33:42
09/05/91	14:16:16	00:00:51	04:36:16
09/05/91	14:18:59	00:00:50	04:38:59
09/05/91	14:21:41	00:00:50	04:41:41
09/05/91	14:24:22	00:00:48	04:44:22
09/05/91	14:27:03	00:00:49	04:47:03
09/05/91	14:29:44	00:00:49	04:49:44
09/05/91	14:32:25	00:00:51	04:52:25
09/05/91	14:35:08	00:00:50	04:55:08
09/05/91	14:37:47	00:00:52	04:57:47
09/05/91	14:40:30	00:00:47	05:00:30
09/05/91	14:43:02	00:00:51	05:03:02
09/05/91	14:45:41	00:00:47	05:05:41
09/05/91	14:48:17	00:00:48	05:08:17
09/05/91	14:50:56	00:00:48	05:10:56
09/05/91	14:53:36	00:00:50	05:13:36
09/05/91	14:56:23	00:00:48	05:16:23
09/05/91	14:59:08	00:00:50	05:19:08
09/05/91	15:01:53	00:00:51	05:21:53
09/05/91	15:04:37	00:00:50	05:24:37
09/05/91	15:07:22	00:00:52	05:27:22
09/05/91	15:10:04	00:00:50	05:30:04
09/05/91	15:12:45	00:00:50	05:32:45
09/05/91	15:15:26	00:00:51	05:35:26
09/05/91	15:18:05	00:00:49	05:38:05
09/05/91	15:20:43	00:00:49	05:40:43
09/05/91	15:23:21	00:00:49	05:43:21
09/05/91	15:26:00	00:00:51	05:46:00
09/05/91	15:28:40	00:00:51	05:48:40

Figure B9

CYCLE TIME
FRONT PUMP ONLY

REAL DATE	REAL TIME	CYCLE TIME	TEST TIME
09/05/91	15:31:20	00:00:53	05:51:20
09/05/91	15:34:04	00:00:51	05:54:04
09/05/91	15:36:43	00:00:53	05:56:43
09/05/91	15:39:26	00:00:50	05:59:26
09/05/91	15:42:07	00:00:50	06:02:07
09/05/91	15:44:47	00:00:50	06:04:47
09/05/91	15:47:26	00:00:51	06:07:26
09/05/91	15:50:08	00:00:49	06:10:08
09/05/91	15:52:47	00:00:48	06:12:47
09/05/91	15:55:23	00:00:50	06:15:23
09/05/91	15:58:01	00:00:50	06:18:01
09/05/91	16:00:40	00:00:51	06:20:40
09/05/91	16:03:23	00:00:51	06:23:23
09/05/91	16:06:03	00:00:52	06:26:03
09/05/91	16:08:43	00:00:48	06:28:43
09/05/91	16:11:19	00:00:49	06:31:19
09/05/91	16:13:58	00:00:50	06:33:58
09/05/91	16:16:37	00:00:52	06:36:37
09/05/91	16:19:18	00:00:50	06:39:18
09/05/91	16:21:59	00:00:52	06:41:59
09/05/91	16:24:43	00:00:48	06:44:43
09/05/91	16:27:20	00:00:51	06:47:20
09/05/91	16:30:00	00:00:52	06:50:00
09/05/91	16:32:39	00:00:53	06:52:39
09/05/91	16:35:19	00:00:54	06:55:19
09/05/91	16:38:01	00:00:57	06:58:01
09/05/91	16:40:50	00:00:54	07:00:50
09/05/91	16:43:38	00:00:52	07:03:38
09/05/91	16:46:20	00:00:53	07:06:20
09/05/91	16:49:02	00:00:52	07:09:02
09/05/91	16:51:40	00:00:52	07:11:40
09/05/91	16:54:15	00:00:54	07:14:15
09/05/91	16:56:54	00:00:53	07:16:54
09/05/91	16:59:34	00:00:53	07:19:34
09/05/91	17:02:14	00:00:53	07:22:14
09/05/91	17:04:54	00:00:52	07:24:54
09/05/91	17:07:33	00:00:49	07:27:33
09/05/91	17:10:06	00:00:49	07:30:06
09/05/91	17:12:39	00:00:50	07:32:39
09/05/91	17:15:12	00:00:49	07:35:12
09/05/91	17:17:44	00:00:51	07:37:44
09/05/91	17:20:16	00:00:52	07:40:16
09/05/91	17:22:52	00:00:51	07:42:52
09/05/91	17:25:29	00:00:50	07:45:29
09/05/91	17:28:07	00:00:50	07:48:07
09/05/91	17:30:47	00:00:53	07:50:47
09/05/91	17:33:35	00:00:51	07:53:35
09/05/91	17:36:17	00:00:49	07:56:17
09/05/91	17:38:57	00:00:52	07:58:57
09/05/91	17:41:39	00:00:49	08:01:39

REAL DATE	REAL TIME	CYCLE TIME	TEST TIME
09/05/91	17:44:19	00:00:48	08:04:19
09/05/91	17:46:59	00:00:47	08:06:59
09/05/91	17:49:42	00:00:47	08:09:42
09/05/91	17:52:28	00:00:49	08:12:28
09/05/91	17:55:20	00:00:49	08:15:20
09/05/91	17:58:09	00:00:50	08:18:09
09/05/91	18:00:58	00:00:50	08:20:58
09/05/91	18:03:44	00:00:48	08:23:44
09/05/91	18:06:29	00:00:50	08:26:29
09/05/91	18:09:16	00:00:49	08:29:16
09/05/91	18:12:03	00:00:50	08:32:03
09/05/91	18:14:50	00:00:51	08:34:50
09/05/91	18:17:38	00:00:51	08:37:38
09/05/91	18:20:26	00:00:51	08:40:26
09/05/91	18:23:14	00:00:50	08:43:14
09/05/91	18:26:04	00:00:50	08:46:04
09/05/91	18:28:53	00:00:51	08:48:53
09/05/91	18:31:41	00:00:54	08:51:41
09/05/91	18:34:31	00:00:53	08:54:31
09/05/91	18:37:19	00:00:48	08:57:19
09/05/91	18:39:59	00:00:59	08:59:59
09/05/91	18:42:48	00:01:01	09:02:48
09/05/91	18:45:35	00:01:02	09:05:35
09/05/91	18:48:22	00:01:02	09:08:22
09/05/91	18:51:06	00:00:58	09:11:06
09/05/91	18:53:46	00:00:59	09:13:46
09/05/91	18:56:26	00:00:59	09:16:26
09/05/91	18:59:05	00:00:59	09:19:05
09/05/91	19:01:45	00:00:59	09:21:45
09/05/91	19:04:22	00:01:00	09:24:22
09/05/91	19:06:58	00:01:05	09:26:58
09/05/91	19:09:41	00:01:05	09:29:41
09/05/91	19:12:22	00:01:08	09:32:22
09/05/91	19:15:08	00:01:06	09:35:08
09/05/91	19:17:50	00:01:04	09:37:50
09/05/91	19:20:25	00:01:06	09:40:25
09/05/91	19:23:03	00:01:03	09:43:03
09/05/91	19:25:36	00:01:05	09:45:36
09/05/91	19:28:11	00:01:04	09:48:11
09/05/91	19:30:47	00:01:03	09:50:47
09/05/91	19:33:20	00:01:06	09:53:20
09/05/91	19:35:56	00:01:06	09:55:56
09/05/91	19:38:31	00:01:05	09:58:31
09/05/91	19:41:06	00:01:05	10:01:06
09/05/91	19:43:38	00:01:06	10:03:38
09/05/91	19:46:15	00:01:06	10:06:15
09/05/91	19:48:49	00:01:08	10:08:49
09/05/91	19:51:24	00:01:09	10:11:24
09/05/91	19:54:01	00:01:08	10:14:01
09/05/91	19:56:36	00:01:09	10:16:36

CYCLE TIME
FRONT PUMP ONLY

REAL DATE	REAL TIME	CYCLE TIME	TEST TIME
09/05/91	19:59:11	00:01:11	10:19:11
09/05/91	20:01:46	00:01:12	10:21:46
09/05/91	20:04:23	00:01:12	10:24:23
09/05/91	20:07:00	00:01:09	10:27:00
09/05/91	20:09:33	00:01:13	10:29:33
09/05/91	20:12:10	00:01:12	10:32:10
09/05/91	20:14:46	00:01:12	10:34:46
09/05/91	20:17:22	00:01:12	10:37:22
09/05/91	20:19:54	00:01:05	10:39:54
09/05/91	20:22:20	00:01:06	10:42:20
09/05/91	20:24:48	00:01:06	10:44:48
09/05/91	20:27:16	00:01:07	10:47:16
09/05/91	20:29:44	00:01:08	10:49:44
09/05/91	20:32:10	00:01:10	10:52:10
09/05/91	20:34:38	00:01:09	10:54:38
09/05/91	20:37:08	00:01:07	10:57:08
09/05/91	20:39:35	00:01:09	10:59:35
09/05/91	20:42:03	00:01:10	11:02:03
09/05/91	20:44:31	00:01:09	11:04:31
09/05/91	20:46:58	00:01:07	11:06:58
09/05/91	20:49:20	00:01:11	11:09:20
09/05/91	20:51:46	00:01:12	11:11:46
09/05/91	20:54:11	00:01:13	11:14:11
09/05/91	20:56:37	00:01:11	11:16:37
09/05/91	20:59:02	00:01:11	11:19:02

REAL DATE	REAL TIME	CYCLE TIME	TEST TIME
09/05/91	21:01:26	00:01:10	11:21:26
09/05/91	21:03:49	00:01:12	11:23:49
09/05/91	21:06:18	00:01:15	11:26:18
09/05/91	21:08:49	00:01:12	11:28:49
09/05/91	21:11:15	00:01:10	11:31:15
09/05/91	21:13:37	00:01:10	11:33:37
09/05/91	21:16:01	00:01:10	11:36:01
09/05/91	21:18:22	00:01:11	11:38:22
09/05/91	21:20:43	00:01:12	11:40:43
09/05/91	21:23:05	00:01:08	11:43:05
09/05/91	21:25:25	00:01:11	11:45:25
09/05/91	21:27:47	00:01:10	11:47:47
09/05/91	21:30:08	00:01:14	11:50:08
09/05/91	21:32:32	00:01:14	11:52:32
09/05/91	21:34:55	00:01:15	11:54:55
09/05/91	21:37:18	00:01:15	11:57:18
09/05/91	21:39:43	00:01:14	11:59:43

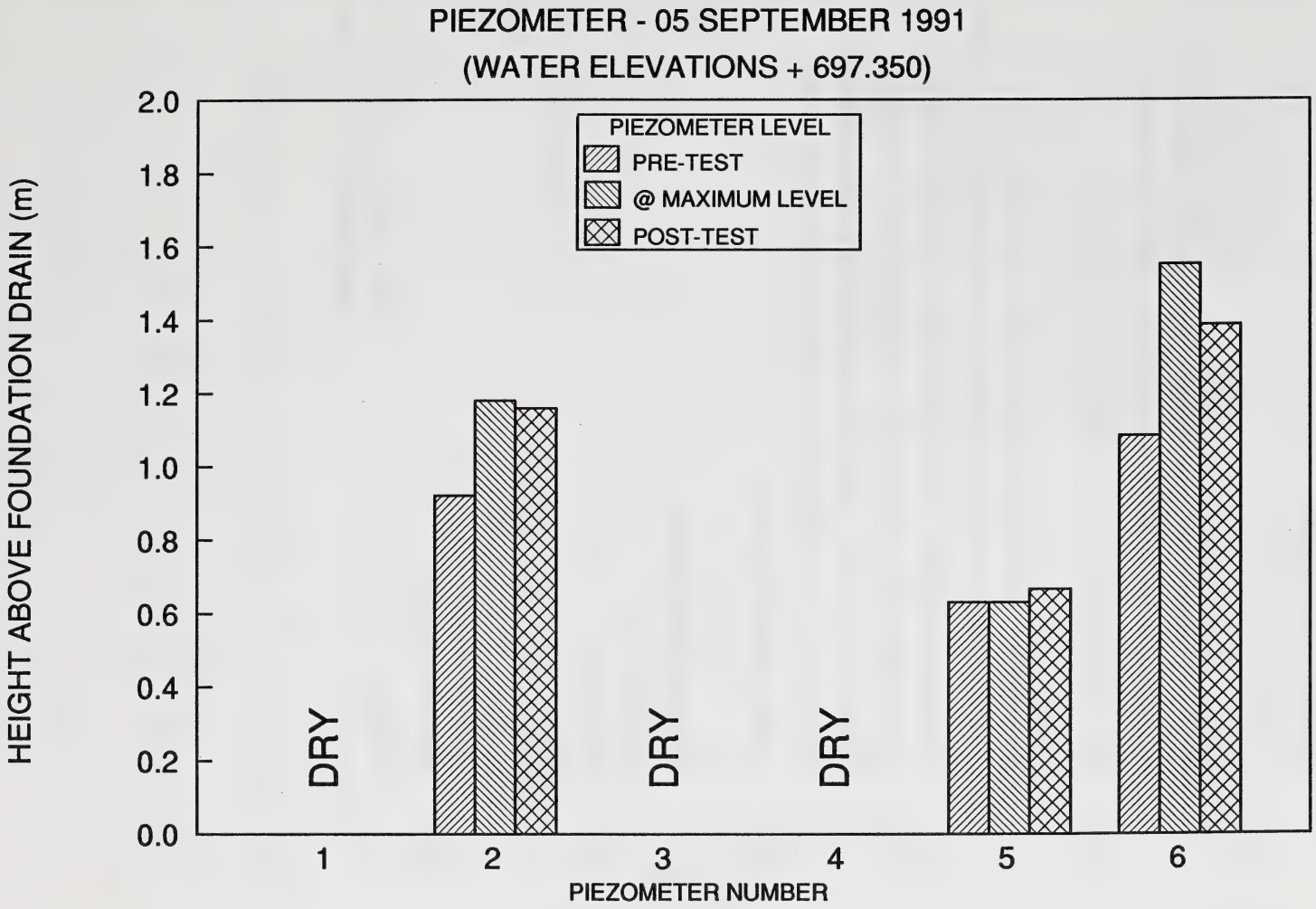
PIEZOMETER - 05 SEPTEMBER 1991
(WATER ELEVATIONS + 697.350)
HEIGHT ABOVE FOUNDATION DRAIN (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
PIEZOMETER LEVEL
PRE-TEST
@ MAXIMUM LEVEL
POST-TEST
DRY
DRY
DRY
1
2
3
4
5
6
PIEZOMETER NUMBER

Figure B10

1.3 September 6, 1991 Results

Large Sump, Splash Pad

The site configuration for this simulation was a single lot and the back-yard (side-yard discharge) sump was used (Sump 1). The sump water was discharged to a typical concrete splash pad.

As indicated by the storm hyetograph, the simulated rainfall had to be stopped part way through the test when the pump failed in Sump 1. Sump 1 started to fill; Sump 2 valve was opened and the valve for Sump 1 closed to allow the pump to be repaired. A rock from the base of the sump had lodged in the impeller. The rock was removed and the pump reassembled and reinstalled. For the remainder of the test both sump systems were needed to handle the inflow.

Simulated Data Summary

Simulated event	4 hours, 1:5
Test started at	12:30 p.m.
Weather	Sunny, 26° C, calm
Total volume of water applied	N/A
Maximum inflow	2.5 L/s
Maximum recycled	1.8 L/s
Maximum pump cycle time	Sump Pump 1 - 6 min, 31 sec.
	Sump Pump 2 - 7 min, 14 sec.

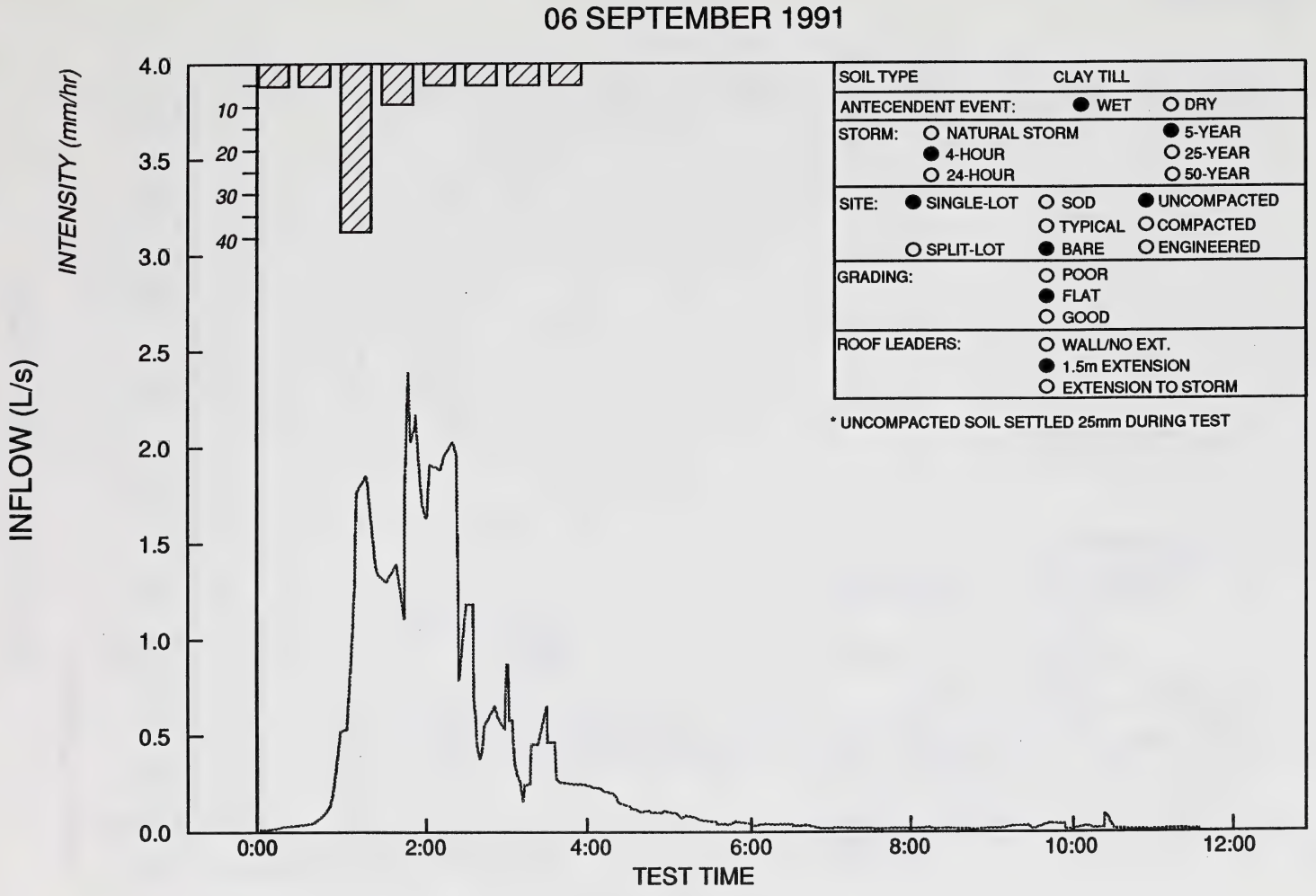
06 SEPTEMBER 1991
INFLOW (L/s)
INTENSITY (mm/hr)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10
20
30
40
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 4-HOUR ○ 24-HOUR ● 5-YEAR ○ 25-YEAR ○ 50-YEAR
SITE: ● SINGLE-LOT ○ SPLIT-LOT ○ SOD ○ TYPICAL ● BARE ● UNCOMPACTED ○ COMPACTED ○ ENGINEERED
GRADING: ○ POOR ● FLAT ○ GOOD
ROOF LEADERS: ○ WALL/NO EXT. ● 1.5m EXTENSION ○ EXTENSION TO STORM
* UNCOMPACTED SOIL SETTLED 25mm DURING TEST

Figure B11

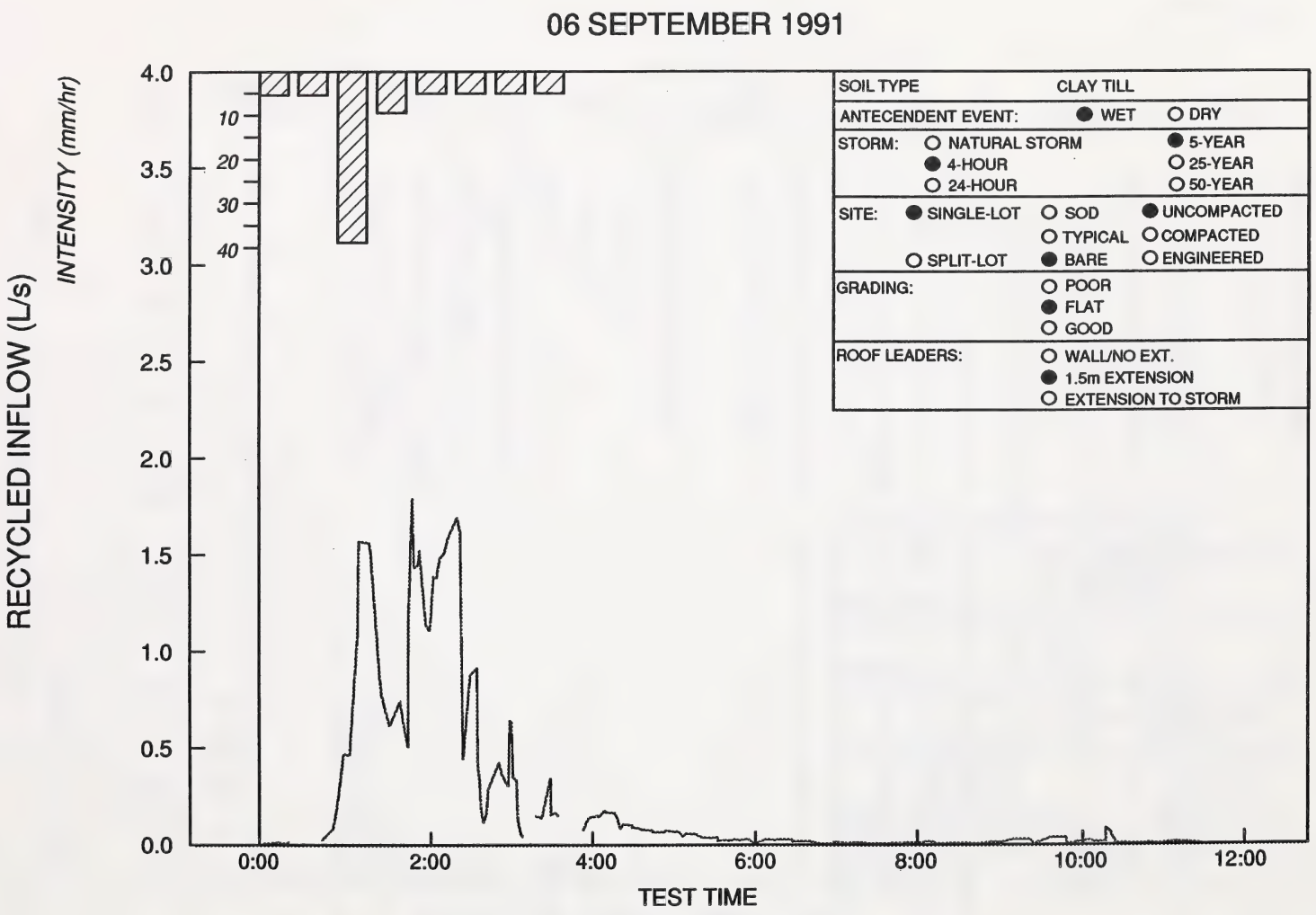
06 SEPTEMBER 1991
RECYCLED INFLOW (L/s)
INTENSITY (mm/hr)
10
20
30
40
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 5-YEAR ● 4-HOUR ○ 25-YEAR ○ 24-HOUR ○ 50-YEAR
SITE: ● SINGLE-LOT ○ SOD ● UNCOMPACTED ○ TYPICAL ○ COMPACTED ○ SPLIT-LOT ● BARE ○ ENGINEERED
GRADING: ○ POOR ● FLAT ○ GOOD
ROOF LEADERS: ○ WALL/NO EXT. ● 1.5m EXTENSION ○ EXTENSION TO STORM

Figure B12

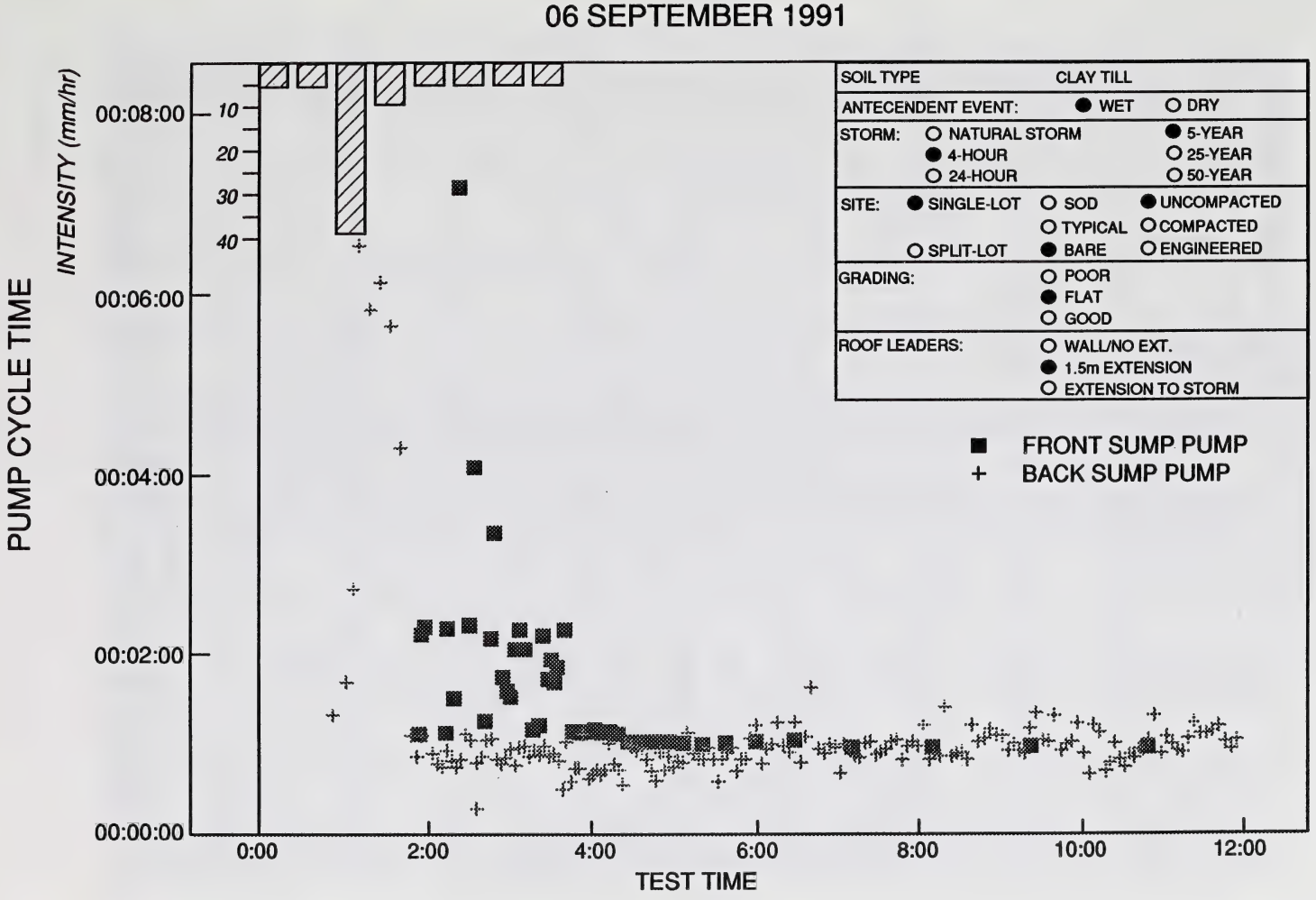
06 SEPTEMBER 1991
PUMP CYCLE TIME
INTENSITY (mm/hr)
10
20
30
40
00:08:00
00:06:00
00:04:00
00:02:00
00:00:00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 5-YEAR
● 4-HOUR ○ 25-YEAR
○ 24-HOUR ○ 50-YEAR
SITE: ● SINGLE-LOT ○ SOD ● UNCOMPACTED
○ TYPICAL ○ COMPACTED
○ SPLIT-LOT ● BARE ○ ENGINEERED
GRADING: ○ POOR
● FLAT
○ GOOD
ROOF LEADERS: ○ WALL/NO EXT.
● 1.5m EXTENSION
○ EXTENSION TO STORM
■ FRONT SUMP PUMP
+ BACK SUMP PUMP

Figure B13

SUMP PUMP CYCLE TIME

REAL DATE	REAL TIME	SUMP PUMP CYCLE TIME BACK	SUMP PUMP CYCLE TIME FRONT	TEST TIME
09/06/91	13:24:53	00:01:20		00:54:53
09/06/91	13:35:10	00:01:42		01:05:10
09/06/91	13:40:18	00:02:44		01:10:18
09/06/91	13:44:43	00:06:35		01:14:43
09/06/91	13:52:52	00:05:52		01:22:52
09/06/91	14:00:17	00:06:10		01:30:17
09/06/91	14:08:04	00:05:41		01:38:04
09/06/91	14:15:24	00:04:19		01:45:24
09/06/91	14:22:51	00:01:06		01:52:51
09/06/91	14:26:52	00:00:52		01:56:52
09/06/91	14:29:08		00:01:07	01:59:08
09/06/91	14:30:23	00:01:06		02:00:23
09/06/91	14:30:26		00:02:14	02:00:26
09/06/91	14:33:15		00:02:19	02:03:15
09/06/91	14:38:43	00:00:54		02:08:43
09/06/91	14:42:27	00:00:47		02:12:27
09/06/91	14:45:48	00:00:45		02:15:48
09/06/91	14:48:15		00:01:08	02:18:15
09/06/91	14:49:02	00:00:56		02:19:02
09/06/91	14:49:33		00:02:18	02:19:33
09/06/91	14:52:34	00:00:49		02:22:34
09/06/91	14:54:15		00:01:31	02:24:15
09/06/91	14:56:01	00:00:45		02:26:01
09/06/91	14:58:18		00:07:14	02:28:18
09/06/91	14:59:14	00:00:50		02:29:14
09/06/91	15:02:32	00:01:07		02:32:32
09/06/91	15:05:32		00:02:20	02:35:32
09/06/91	15:06:39	00:01:03		02:36:39
09/06/91	15:09:10		00:04:06	02:39:10
09/06/91	15:10:33	00:00:17		02:40:33
09/06/91	15:10:57	00:00:48		02:40:57
09/06/91	15:14:29	00:00:52		02:44:29
09/06/91	15:17:04		00:01:16	02:47:04
09/06/91	15:18:01	00:01:03		02:48:01
09/06/91	15:21:46		00:02:11	02:51:46
09/06/91	15:21:55	00:01:04		02:51:55
09/06/91	15:24:15		00:03:22	02:54:15
09/06/91	15:32:21	00:00:51		03:02:21
09/06/91	15:33:04		00:01:36	03:03:04
09/06/91	15:35:43		00:01:32	03:05:43
09/06/91	15:35:47	00:00:57		03:05:47
09/06/91	15:25:46	00:00:50		02:55:46
09/06/91	15:29:06	00:00:47		02:59:06
09/06/91	15:30:15		00:01:45	03:00:15
09/06/91	15:39:02		00:02:04	03:09:02
09/06/91	15:39:18	00:00:46		03:09:18
09/06/91	15:42:20	00:00:58		03:12:20
09/06/91	15:42:41		00:02:17	03:12:41
09/06/91	15:45:55	00:00:59		03:15:55
09/06/91	15:45:55		00:02:04	03:15:55
09/06/91	15:49:33	00:00:52		03:19:33

REAL DATE	REAL TIME	SUMP PUMP CYCLE TIME BACK	SUMP PUMP CYCLE TIME FRONT	TEST TIME
09/06/91	15:51:52		00:01:10	03:21:52
09/06/91	15:53:05	00:00:56		03:23:05
09/06/91	15:56:47		00:01:13	03:26:47
09/06/91	15:56:54	00:00:53		03:26:54
09/06/91	15:59:31		00:02:13	03:29:31
09/06/91	16:00:23	00:00:59		03:30:23
09/06/91	16:03:02		00:01:44	03:33:02
09/06/91	16:04:04	00:00:52		03:34:04
09/06/91	16:05:46		00:01:57	03:35:46
09/06/91	16:07:22	00:00:54		03:37:22
09/06/91	16:08:01		00:01:42	03:38:01
09/06/91	16:09:59		00:01:52	03:39:59
09/06/91	16:10:47	00:00:49		03:40:47
09/06/91	16:13:58	00:00:30		03:43:58
09/06/91	16:15:15		00:02:17	03:45:15
09/06/91	16:16:19	00:01:02		03:46:19
09/06/91	16:20:01	00:00:35		03:50:01
09/06/91	16:21:33		00:01:09	03:51:33
09/06/91	16:22:40	00:00:44		03:52:40
09/06/91	16:25:42	00:00:44		03:55:42
09/06/91	16:26:42		00:01:08	03:56:42
09/06/91	16:28:47	00:01:07		03:58:47
09/06/91	16:31:54		00:01:09	04:01:54
09/06/91	16:33:01	00:00:37		04:03:01
09/06/91	16:35:45	00:00:40		04:05:45
09/06/91	16:37:11		00:01:10	04:07:11
09/06/91	16:38:40	00:00:43		04:08:40
09/06/91	16:41:44	00:00:40		04:11:44
09/06/91	16:42:48		00:01:08	04:12:48
09/06/91	16:44:40	00:00:43		04:14:40
09/06/91	16:47:44	00:01:01		04:17:44
09/06/91	16:48:26		00:01:09	04:18:26
09/06/91	16:51:34	00:00:47		04:21:34
09/06/91	16:54:31		00:01:07	04:24:31
09/06/91	16:54:51	00:00:43		04:24:51
09/06/91	16:57:45	00:00:33		04:27:45
09/06/91	17:00:15	00:01:01		04:30:15
09/06/91	17:02:11		00:01:02	04:32:11
09/06/91	17:04:08	00:00:59		04:34:08
09/06/91	17:08:02	00:00:56		04:38:02
09/06/91	17:11:08		00:01:02	04:41:08
09/06/91	17:11:45	00:00:58		04:41:45
09/06/91	17:15:32	00:00:50		04:45:32
09/06/91	17:19:02	00:00:42		04:49:02
09/06/91	17:21:01		00:01:02	04:51:01
09/06/91	17:22:06	00:00:36		04:52:06
09/06/91	17:24:49	00:00:55		04:54:49
09/06/91	17:28:29	00:00:43		04:58:29
09/06/91	17:31:22		00:01:02	05:01:22
09/06/91	17:31:37	00:00:52		05:01:37
09/06/91	17:35:05	00:00:45		05:05:05

Figure B14

SUMP PUMP CYCLE TIME

REAL DATE	REAL TIME	SUMP PUMP CYCLE TIME BACK	SUMP PUMP CYCLE TIME FRONT	TEST TIME
09/06/91	17:38:15	00:00:49		05:08:15
09/06/91	17:41:41	00:00:48		05:11:41
09/06/91	17:42:31		00:01:01	05:12:31
09/06/91	17:45:02	00:01:08		05:15:02
09/06/91	17:49:22	00:00:54		05:19:22
09/06/91	17:53:05	00:00:50		05:23:05
09/06/91	17:55:44		00:01:00	05:25:44
09/06/91	17:56:34	00:00:50		05:26:34
09/06/91	18:00:00	00:00:58		05:30:00
09/06/91	18:03:53	00:00:50		05:33:53
09/06/91	18:07:17	00:00:35		05:37:17
09/06/91	18:09:57	00:00:50		05:39:57
09/06/91	18:12:40		00:01:01	05:42:40
09/06/91	18:13:19	00:00:55		05:43:19
09/06/91	18:16:56	00:00:58		05:46:56
09/06/91	18:20:45	00:00:42		05:50:45
09/06/91	18:23:48	00:00:50		05:53:48
09/06/91	18:27:11	00:00:50		05:57:11
09/06/91	18:30:35	00:01:04		06:00:35
09/06/91	18:34:40		00:01:02	06:04:40
09/06/91	18:34:42	00:01:13		06:04:42
09/06/91	18:39:06	00:00:47		06:09:06
09/06/91	18:42:22	00:00:57		06:12:22
09/06/91	18:46:07	00:01:00		06:16:07
09/06/91	18:50:06	00:01:15		06:20:06
09/06/91	18:54:52	00:00:59		06:24:52
09/06/91	18:58:53	00:00:55		06:28:53
09/06/91	19:02:29		00:01:03	06:32:29
09/06/91	19:02:38	00:01:15		06:32:38
09/06/91	19:07:11	00:00:48		06:37:11
09/06/91	19:10:36	00:01:05		06:40:36
09/06/91	19:14:48	00:01:38		06:44:48
09/06/91	19:20:35	00:00:57		06:50:35
09/06/91	19:24:33	00:00:54		06:54:33
09/06/91	19:28:13	00:01:00		06:58:13
09/06/91	19:32:17	00:00:58		07:02:17
09/06/91	19:36:11	00:00:41		07:06:11
09/06/91	19:39:14	00:01:00		07:09:14
09/06/91	19:43:10	00:00:56		07:13:10
09/06/91	19:45:21		00:00:58	07:15:21
09/06/91	19:46:59	00:00:52		07:16:59
09/06/91	19:50:38	00:00:51		07:20:38
09/06/91	19:54:11	00:01:01		07:24:11
09/06/91	19:58:17	00:01:02		07:28:17
09/06/91	20:02:26	00:00:53		07:32:26
09/06/91	20:06:09	00:00:55		07:36:09
09/06/91	20:09:55	00:00:57		07:39:55
09/06/91	20:13:48	00:01:02		07:43:48
09/06/91	20:17:58	00:01:03		07:47:58
09/06/91	20:22:10	00:00:50		07:52:10
09/06/91	20:25:44	00:00:59		07:55:44

REAL DATE	REAL TIME	SUMP PUMP CYCLE TIME BACK	SUMP PUMP CYCLE TIME FRONT	TEST TIME
09/06/91	20:29:44	00:01:02		07:59:44
09/06/91	20:33:51	00:00:59		08:03:51
09/06/91	20:37:49	00:01:13		08:07:49
09/06/91	20:42:33	00:00:50		08:12:33
09/06/91	20:44:25		00:00:58	08:14:25
09/06/91	20:46:06	00:00:54		08:16:06
09/06/91	20:49:51	00:00:52		08:19:51
09/06/91	20:53:28	00:01:25		08:23:28
09/06/91	20:58:44	00:00:52		08:28:44
09/06/91	21:02:27	00:00:54		08:32:27
09/06/91	21:06:15	00:00:55		08:36:15
09/06/91	21:10:06	00:00:50		08:40:06
09/06/91	21:13:39	00:01:13		08:43:39
09/06/91	21:18:20	00:01:02		08:48:20
09/06/91	21:22:34	00:01:04		08:52:34
09/06/91	21:26:54	00:01:10		08:56:54
09/06/91	21:31:34	00:01:06		09:01:34
09/06/91	21:36:00	00:01:06		09:06:00
09/06/91	21:40:27	00:00:56		09:10:27
09/06/91	21:44:23	00:01:01		09:14:23
09/06/91	21:48:33	00:00:56		09:18:33
09/06/91	21:52:29	00:00:54		09:22:29
09/06/91	21:56:18	00:01:11		09:26:18
09/06/91	21:57:09		00:00:59	09:27:09
09/06/91	22:00:48	00:01:21		09:30:48
09/06/91	22:05:57	00:01:03		09:35:57
09/06/91	22:10:15	00:01:02		09:40:15
09/06/91	22:14:24	00:01:19		09:44:24
09/06/91	22:19:27	00:00:56		09:49:27
09/06/91	22:23:24	00:01:00		09:53:24
09/06/91	22:27:28	00:01:02		09:57:28
09/06/91	22:31:39	00:01:14		10:01:39
09/06/91	22:36:28	00:00:54		10:06:28
09/06/91	22:40:16	00:00:40		10:10:16
09/06/91	22:43:18	00:01:13		10:13:18
09/06/91	22:47:58	00:01:08		10:17:58
09/06/91	22:52:27	00:00:42		10:22:27
09/06/91	22:55:36	00:00:48		10:25:36
09/06/91	22:59:01	00:01:01		10:29:01
09/06/91	23:03:03	00:00:50		10:33:03
09/06/91	23:06:36	00:00:45		10:36:36
09/06/91	23:09:52	00:00:53		10:39:52
09/06/91	23:13:29	00:00:51		10:43:29
09/06/91	23:16:59	00:00:57		10:46:59
09/06/91	23:20:47	00:00:56		10:50:47
09/06/91	23:23:38		00:00:58	10:53:38
09/06/91	23:24:35	00:01:03		10:54:35
09/06/91	23:28:45	00:01:19		10:58:45
09/06/91	23:33:45	00:00:54		11:03:45
09/06/91	23:37:35	00:01:05		11:07:35
09/06/91	23:41:51	00:01:00		11:11:51

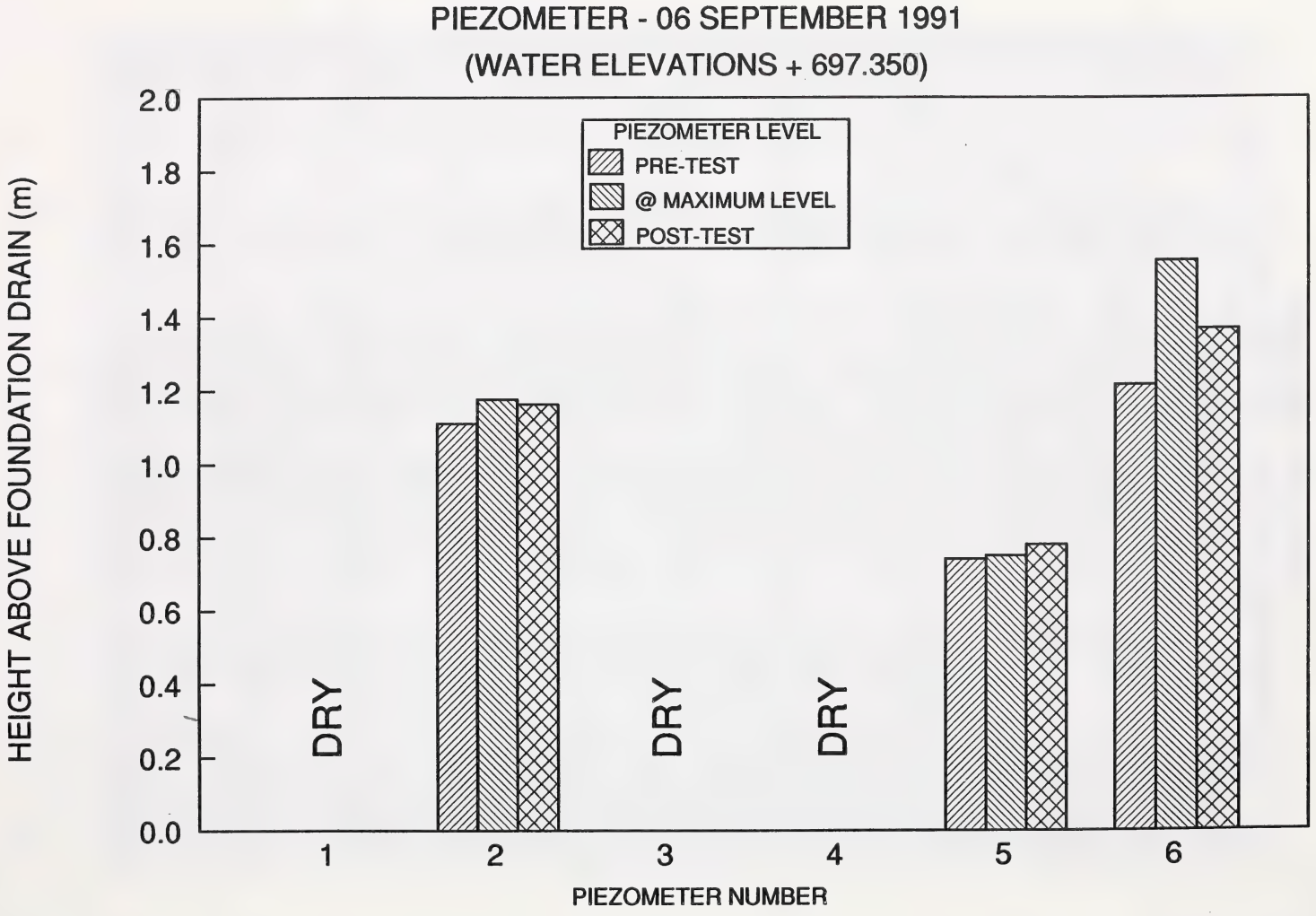
PIEZOMETER - 06 SEPTEMBER 1991
(WATER ELEVATIONS + 697.350)
PIEZOMETER LEVEL
PRE-TEST
@ MAXIMUM LEVEL
POST-TEST
HEIGHT ABOVE FOUNDATION DRAIN (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
DRY
DRY
DRY
1
2
3
4
5
6
PIEZOMETER NUMBER

Figure B15

1.4 September 7, 1991 Results

Small Sump, Splash Pad

For this simulation the uncompacted backfill had settled considerably and the site would be defined as very poor grading. Settling of approximately 250 mm at the foundation wall had occurred. The site was tested in this condition since it represents common settling under decks and steps. The front sump, Sump 2, was used and the sump discharge was to a splash pad. Approximately 2 hours into the simulation, Sump Pump 2 failed and, similar to the previous test, Sump 1 was activated to prevent basement flooding. Again, a rock lodged in the impeller was the cause of pump failure.

Simulated Data Summary

Simulated event	4 hours, 1:5
Test started at	11:15 a.m.
Weather	Sunny, 28° C, calm
Total volume of water applied	22.04 m^3
Maximum inflow	2.7 L/s
Maximum recycled	2.5 L/s
Maximum pump cycle time	Sump Pump 1 - 4 min, 56 sec.
	Sump Pump 2 - 4 min, 52 sec.

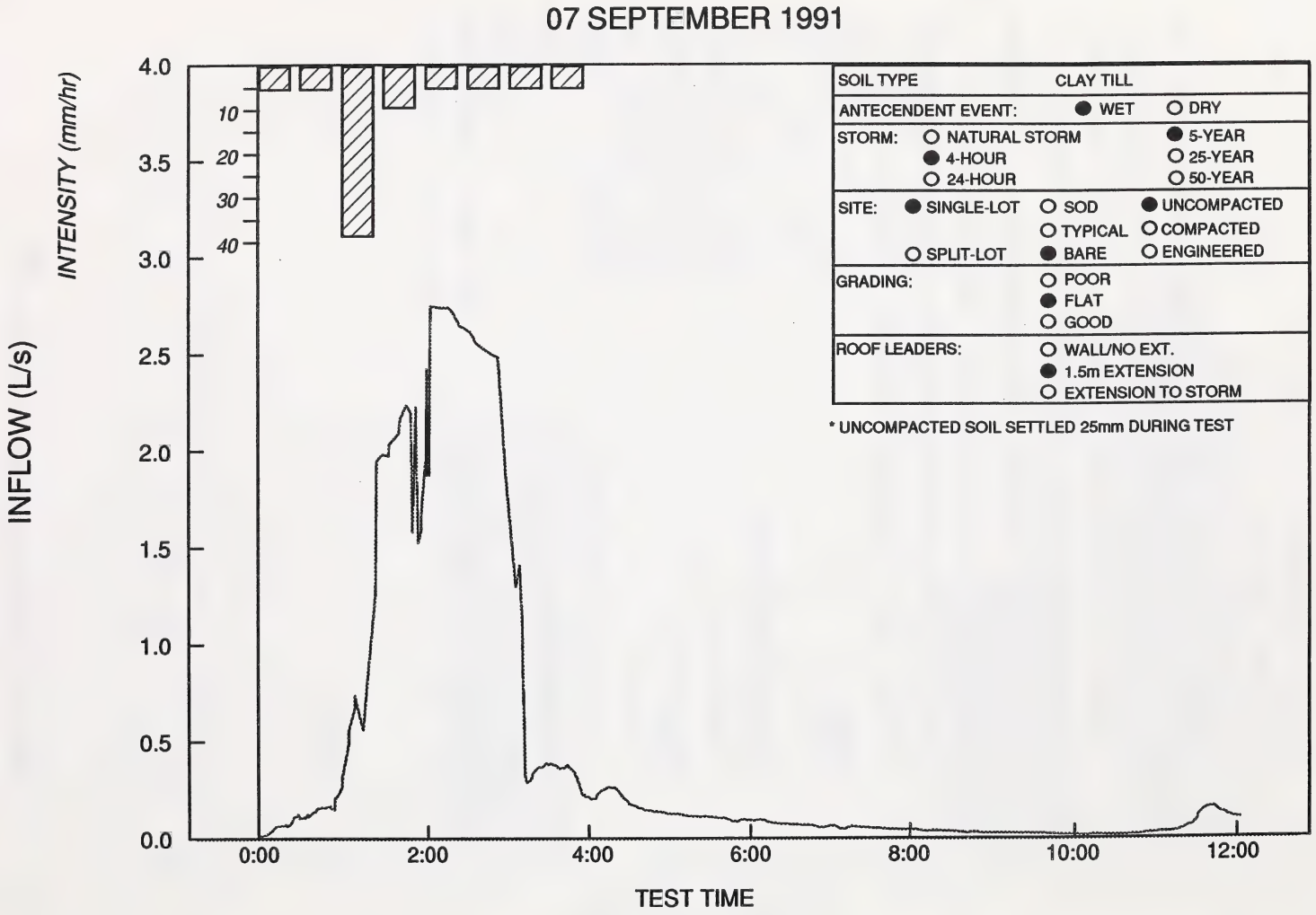
07 SEPTEMBER 1991
INFLOW (L/s)
INTENSITY (mm/hr)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10
20
30
40
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 4-HOUR ○ 24-HOUR ○ 5-YEAR ○ 25-YEAR ○ 50-YEAR
SITE: ● SINGLE-LOT ○ SPLIT-LOT ○ SOD ○ TYPICAL ● BARE ● UNCOMPACTED ○ COMPACTED ○ ENGINEERED
GRADING: ○ POOR ● FLAT ○ GOOD
ROOF LEADERS: ○ WALL/NO EXT. ● 1.5m EXTENSION ○ EXTENSION TO STORM
* UNCOMPACTED SOIL SETTLED 25mm DURING TEST

Figure B16

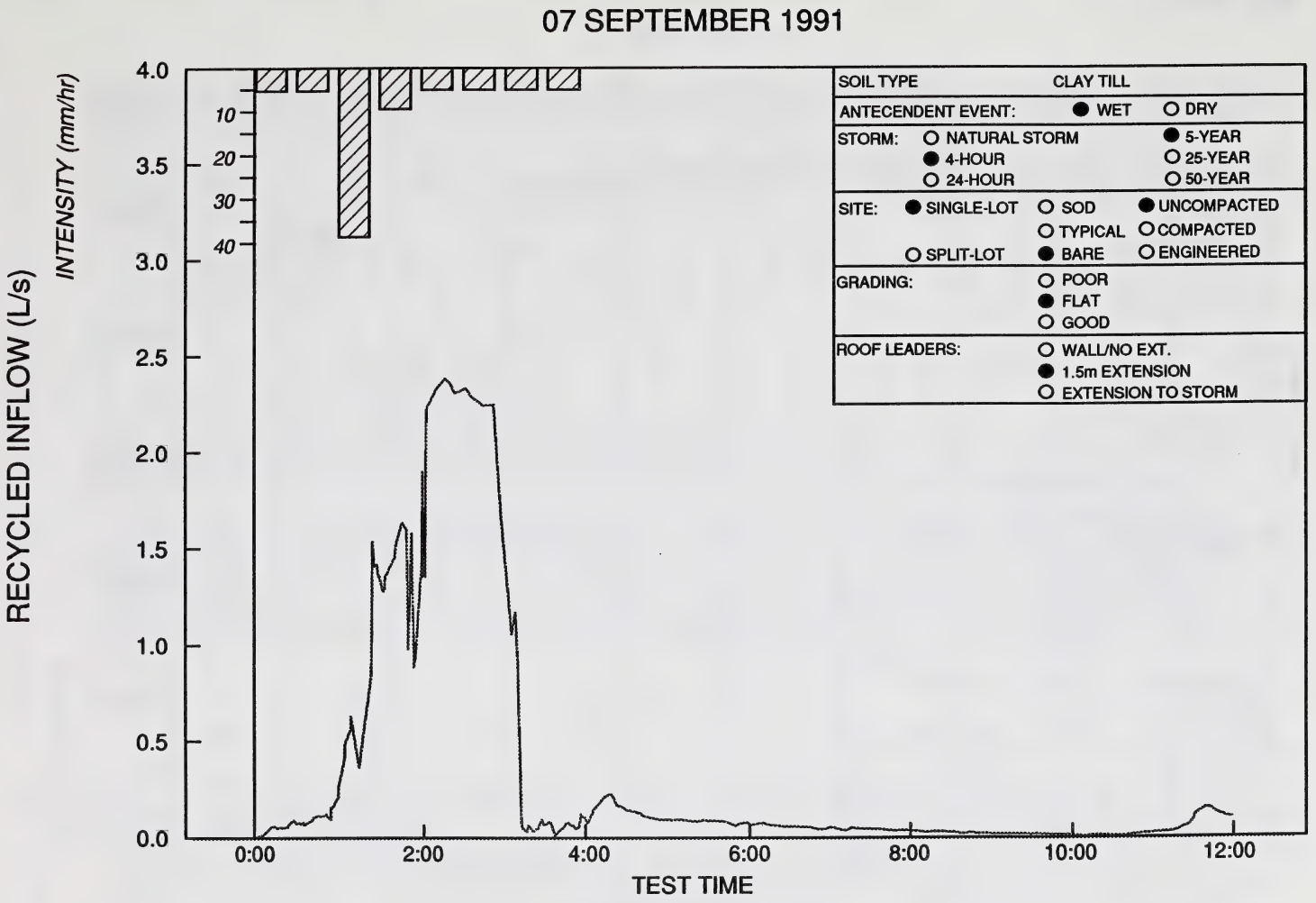
07 SEPTEMBER 1991
RECYCLED INFLOW (L/s)
INTENSITY (mm/hr)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10
20
30
40
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 5-YEAR
● 4-HOUR ○ 25-YEAR
○ 24-HOUR ○ 50-YEAR
SITE: ● SINGLE-LOT ○ SOD ● UNCOMPACTED
○ TYPICAL ○ COMPACTED
○ SPLIT-LOT ● BARE ○ ENGINEERED
GRADING: ○ POOR
● FLAT
○ GOOD
ROOF LEADERS: ○ WALL/NO EXT.
● 1.5m EXTENSION
○ EXTENSION TO STORM

Figure B17

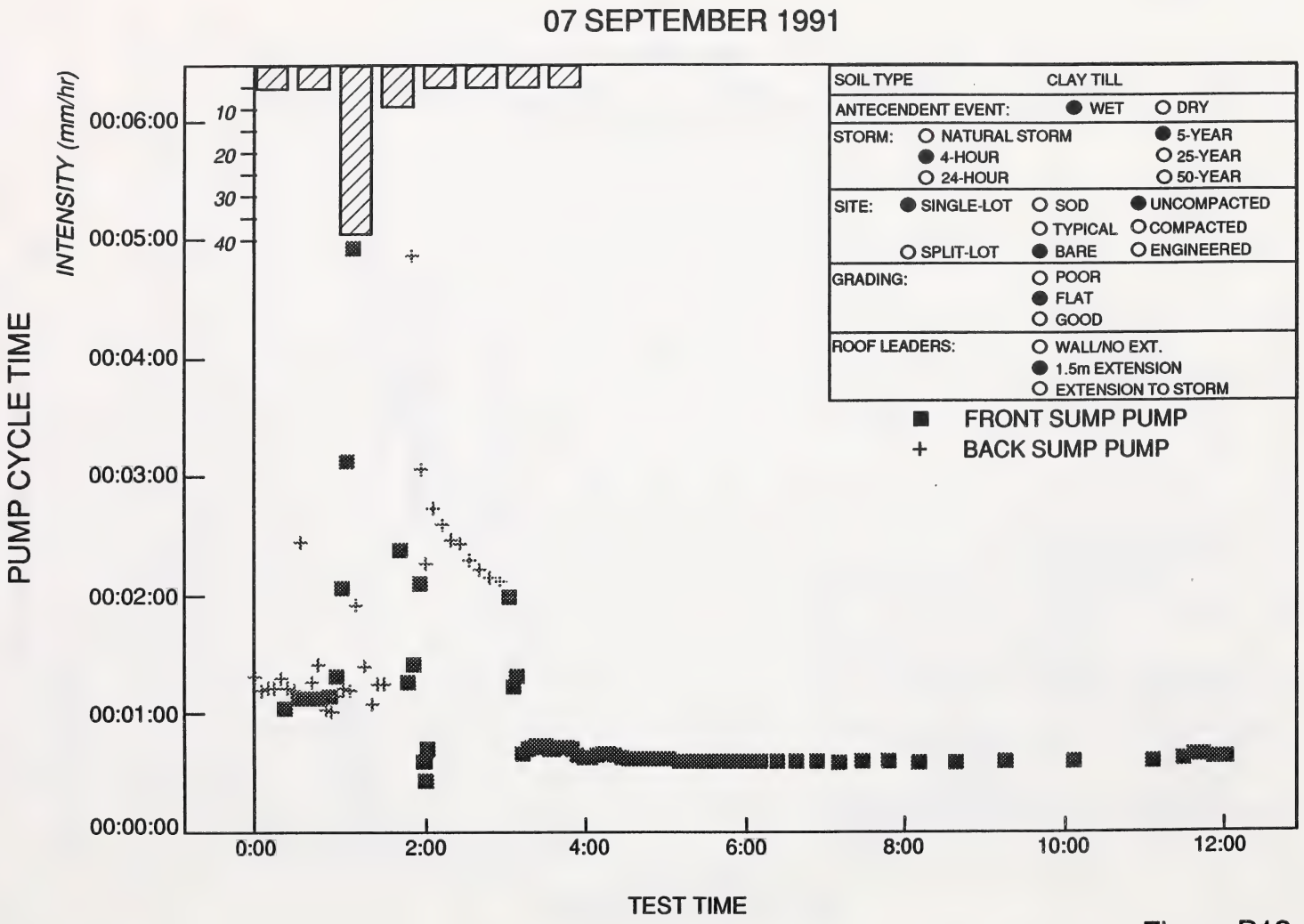
07 SEPTEMBER 1991
INTENSITY (mm/hr)
10
20
30
40
PUMP CYCLE TIME
00:06:00
00:05:00
00:04:00
00:03:00
00:02:00
00:01:00
00:00:00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 5-YEAR
● 4-HOUR ○ 25-YEAR
○ 24-HOUR ○ 50-YEAR
SITE: ● SINGLE-LOT ○ SOD ● UNCOMPACTED
○ TYPICAL ○ COMPACTED
○ SPLIT-LOT ● BARE ○ ENGINEERED
GRADING: ○ POOR
● FLAT
○ GOOD
ROOF LEADERS: ○ WALL/NO EXT.
● 1.5m EXTENSION
○ EXTENSION TO STORM
■ FRONT SUMP PUMP
+ BACK SUMP PUMP

Figure B18

SUMP PUMP CYCLE TIME

REAL DATE	REAL TIME	SUMP PUMP CYCLE TIME BACK	SUMP PUMP CYCLE TIME FRONT	TEST TIME
09/07/91	11:15:45	00:01:19		00:00:45
09/07/91	11:20:48	00:01:12		00:05:48
09/07/91	11:25:30	00:01:13		00:10:30
09/07/91	11:30:14	00:01:13		00:15:14
09/07/91	11:34:58	00:01:18		00:19:58
09/07/91	11:37:40		00:01:03	00:22:40
09/07/91	11:39:59	00:01:13		00:24:59
09/07/91	11:44:45	00:01:12		00:29:45
09/07/91	11:47:53		00:01:08	00:32:53
09/07/91	11:49:27	00:02:27		00:34:27
09/07/91	11:56:05		00:01:08	00:41:05
09/07/91	11:57:23	00:01:16		00:42:23
09/07/91	12:02:19	00:01:25		00:47:19
09/07/91	12:03:32		00:01:08	00:48:32
09/07/91	12:07:35	00:01:02		00:52:35
09/07/91	12:10:28		00:01:09	00:55:28
09/07/91	12:11:56	00:01:01		00:56:56
09/07/91	12:15:49		00:01:19	01:00:49
09/07/91	12:16:13	00:01:09		01:01:13
09/07/91	12:19:41		00:02:04	01:04:41
09/07/91	12:20:42	00:01:13		01:05:42
09/07/91	12:23:14		00:03:08	01:08:14
09/07/91	12:25:19	00:01:12		01:10:19
09/07/91	12:27:37		00:04:56	01:12:37
09/07/91	12:29:55	00:01:55		01:14:55
09/07/91	12:33:37		00:25:43	01:18:37
09/07/91	12:36:28	00:01:24		01:21:28
09/07/91	12:41:39	00:01:05		01:26:39
09/07/91	12:45:56	00:01:15		01:30:56
09/07/91	12:50:39	00:01:15		01:35:39
09/07/91	13:02:15		00:02:23	01:47:15
09/07/91	13:08:08		00:01:16	01:53:08
09/07/91	13:10:41	00:04:52		01:55:41
09/07/91	13:12:13		00:01:25	01:57:13
09/07/91	13:16:46		00:02:06	02:01:46
09/07/91	13:17:43	00:03:04		02:02:43
09/07/91	13:19:21		00:00:36	02:04:21
09/07/91	13:20:11		00:00:36	02:05:11
09/07/91	13:21:03	00:02:16	00:00:26	02:06:03
09/07/91	13:22:09		00:00:42	02:07:09
09/07/91	13:26:50	00:02:44		02:11:50
09/07/91	13:33:17	00:02:36		02:18:17
09/07/91	13:39:48	00:02:28		02:24:48
09/07/91	13:46:27	00:02:26		02:31:27
09/07/91	13:53:17	00:02:18		02:38:17
09/07/91	14:00:29	00:02:13		02:45:29
09/07/91	14:08:00	00:02:09		02:53:00
09/07/91	14:15:31	00:02:07		03:00:31
09/07/91	14:22:41		00:01:59	03:07:41
09/07/91	14:23:02	00:01:59		03:08:02
09/07/91	14:25:54		00:01:14	03:10:54

REAL DATE	REAL TIME	SUMP PUMP CYCLE TIME BACK	SUMP PUMP CYCLE TIME FRONT	TEST TIME
09/07/91	14:28:20		00:01:19	03:13:20
09/07/91	14:32:23		00:00:40	03:17:23
09/07/91	14:36:35		00:00:42	03:21:35
09/07/91	14:39:52		00:00:43	03:24:52
09/07/91	14:43:00		00:00:44	03:28:00
09/07/91	14:46:11		00:00:43	03:31:11
09/07/91	14:49:22		00:00:44	03:34:22
09/07/91	14:52:39		00:00:42	03:37:39
09/07/91	14:55:49		00:00:42	03:40:49
09/07/91	14:59:00		00:00:43	03:44:00
09/07/91	15:02:12		00:00:43	03:47:12
09/07/91	15:05:28		00:00:43	03:50:28
09/07/91	15:08:58		00:00:42	03:53:58
09/07/91	15:12:42		00:00:39	03:57:42
09/07/91	15:17:34		00:00:38	04:02:34
09/07/91	15:22:45		00:00:38	04:07:45
09/07/91	15:27:46		00:00:39	04:12:46
09/07/91	15:32:12		00:00:40	04:17:12
09/07/91	15:36:33		00:00:40	04:21:33
09/07/91	15:40:55		00:00:39	04:25:55
09/07/91	15:45:59		00:00:38	04:30:59
09/07/91	15:51:48		00:00:37	04:36:48
09/07/91	15:58:15		00:00:37	04:43:15
09/07/91	16:05:19		00:00:37	04:50:19
09/07/91	16:12:56		00:00:37	04:57:56
09/07/91	16:20:53		00:00:37	05:05:53
09/07/91	16:29:23		00:00:36	05:14:23
09/07/91	16:38:12		00:00:36	05:23:12
09/07/91	16:47:20		00:00:36	05:32:20
09/07/91	16:56:55		00:00:36	05:41:55
09/07/91	17:06:52		00:00:36	05:51:52
09/07/91	17:17:24		00:00:36	06:02:24
09/07/91	17:28:30		00:00:36	06:13:30
09/07/91	17:41:03		00:00:36	06:26:03
09/07/91	17:55:14		00:00:36	06:40:14
09/07/91	18:10:26		00:00:36	06:55:26
09/07/91	18:26:49		00:00:35	07:11:49
09/07/91	18:43:59		00:00:36	07:28:59
09/07/91	19:03:35		00:00:36	07:48:35
09/07/91	19:26:28		00:00:35	08:11:28
09/07/91	19:53:46		00:00:35	08:38:46
09/07/91	20:30:33		00:00:36	09:15:33
09/07/91	21:21:21		00:00:36	10:06:21
09/07/91	22:20:22		00:00:36	11:05:22
09/07/91	22:42:57		00:00:37	11:27:57
09/07/91	22:50:46		00:00:39	11:35:46
09/07/91	22:57:16		00:00:39	11:42:16
09/07/91	23:05:15		00:00:38	11:50:15
09/07/91	23:14:31		00:00:38	11:59:31
09/07/91	23:24:29		00:00:39	12:09:29
09/07/91	23:34:42		00:00:39	12:19:42

Figure B19

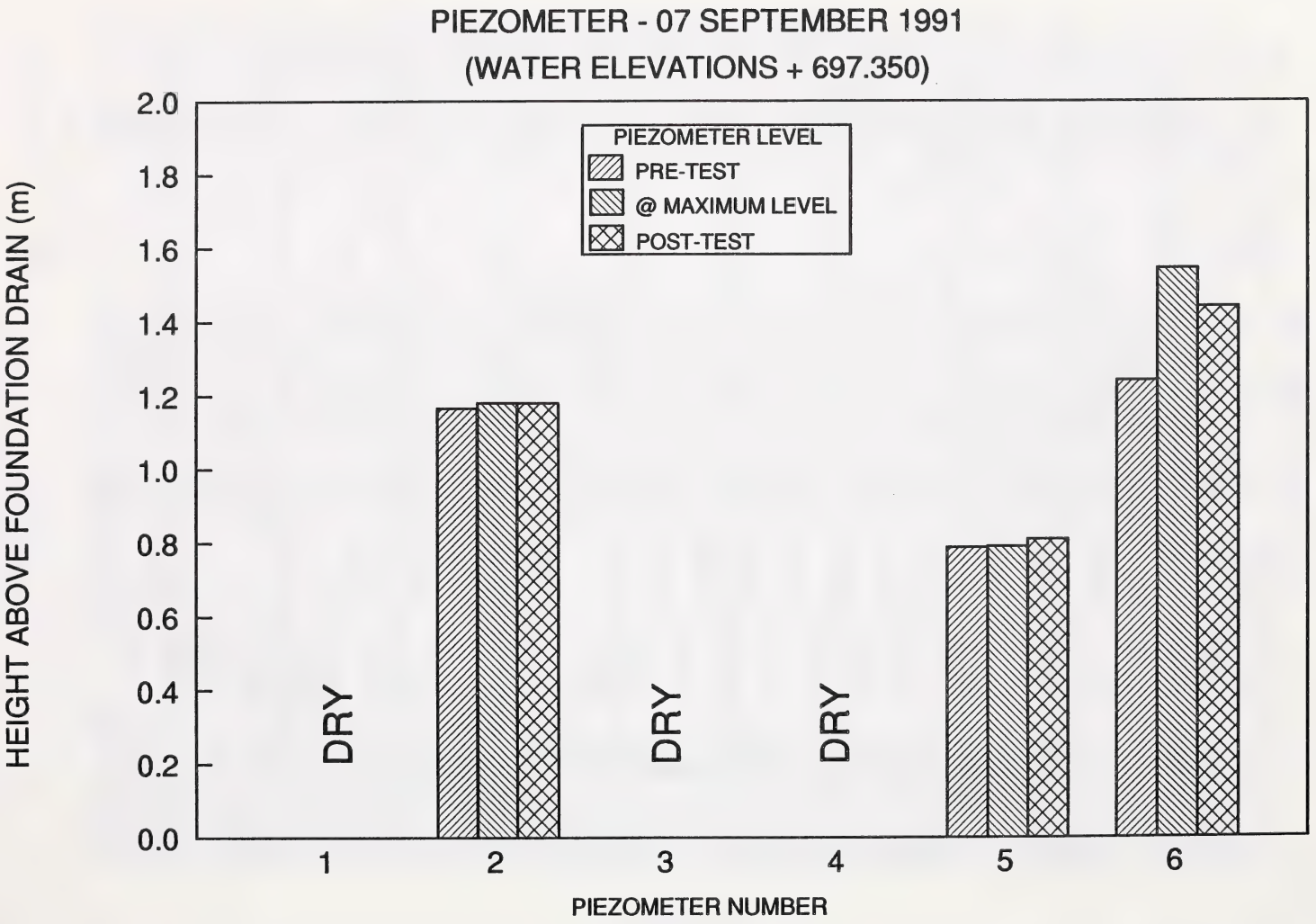
PIEZOMETER - 07 SEPTEMBER 1991
(WATER ELEVATIONS + 697.350)
HEIGHT ABOVE FOUNDATION DRAIN (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
PIEZOMETER LEVEL
PRE-TEST
@ MAXIMUM LEVEL
POST-TEST
DRY
DRY
DRY
1
2
3
4
5
6
PIEZOMETER NUMBER

Figure B20

1.5 Related Testing

Prior to specific field testing for this study, related testing for lot drainage characteristics - clay till soil was carried out at the research facility. The site monitoring and methods of measurements were the same. The clay till tests of July 15, 16, and August 26, 28, 1991 are included to allow for data comparisons.

The only site configurations that vary substantially from the tests of September 3, 5, 6, and 7 are that the sump pump water is discharged off the site and, for the tests of July 15 and 16, the backfill zone is compacted.

For these tests there was no recycled water from sump discharges because of site configuration. The maximum inflow rate for the compacted soil testing of July 15 and 16 is less than 0.1 L/s. For the uncompacted backfill tests of August 26 and 28, the maximum inflow rates are 0.7 L/s and 1.2 L/s, respectively.

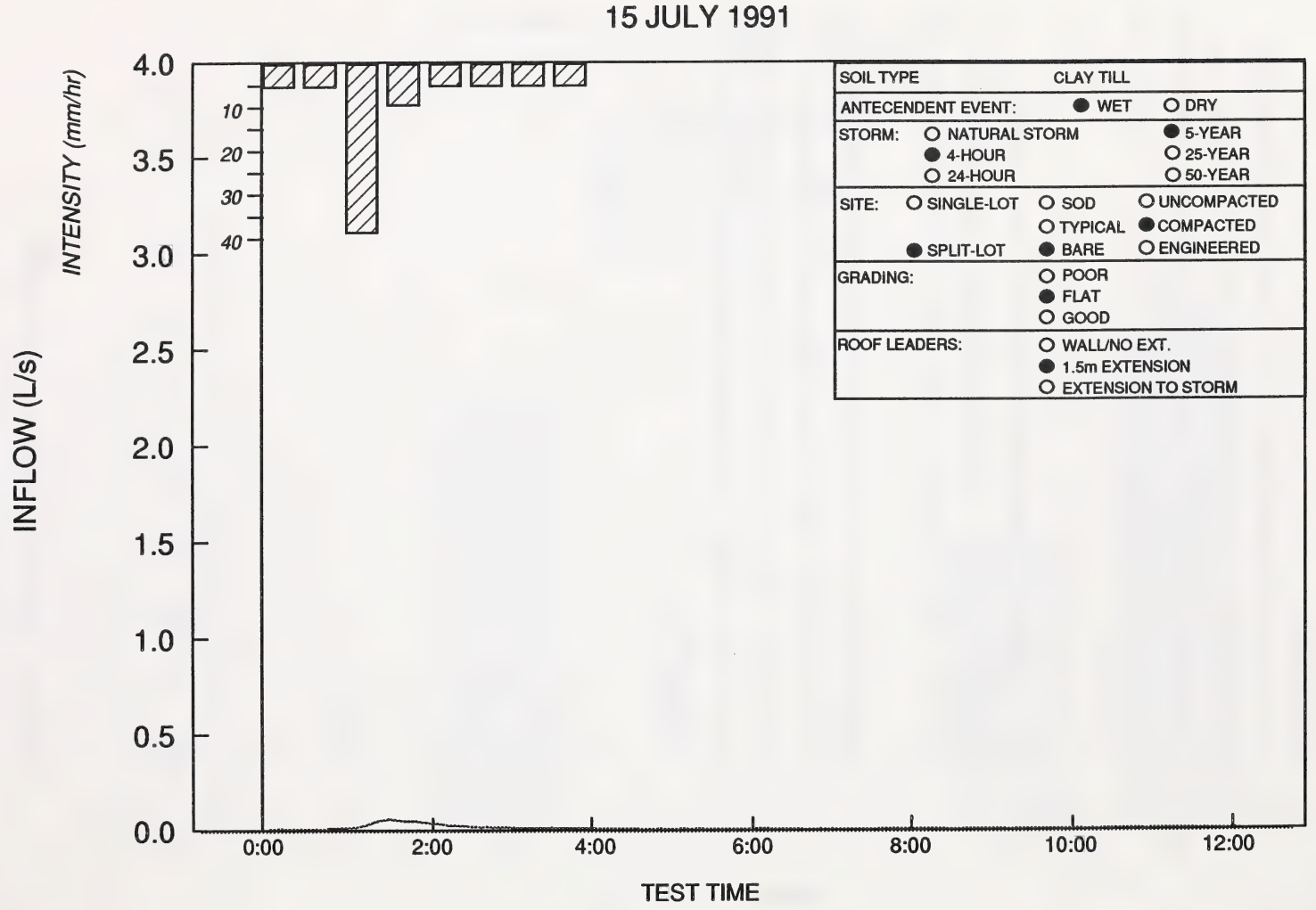
15 JULY 1991
INTENSITY (mm/hr)
10
20
30
40
INFLOW (L/s)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 5-YEAR
● 4-HOUR ○ 25-YEAR
○ 24-HOUR ○ 50-YEAR
SITE: ○ SINGLE-LOT ○ SOD ○ UNCOMPACTED
○ TYPICAL ● COMPACTED
● SPLIT-LOT ● BARE ○ ENGINEERED
GRADING: ○ POOR
● FLAT
○ GOOD
ROOF LEADERS: ○ WALL/NO EXT.
● 1.5m EXTENSION
○ EXTENSION TO STORM

Figure B21

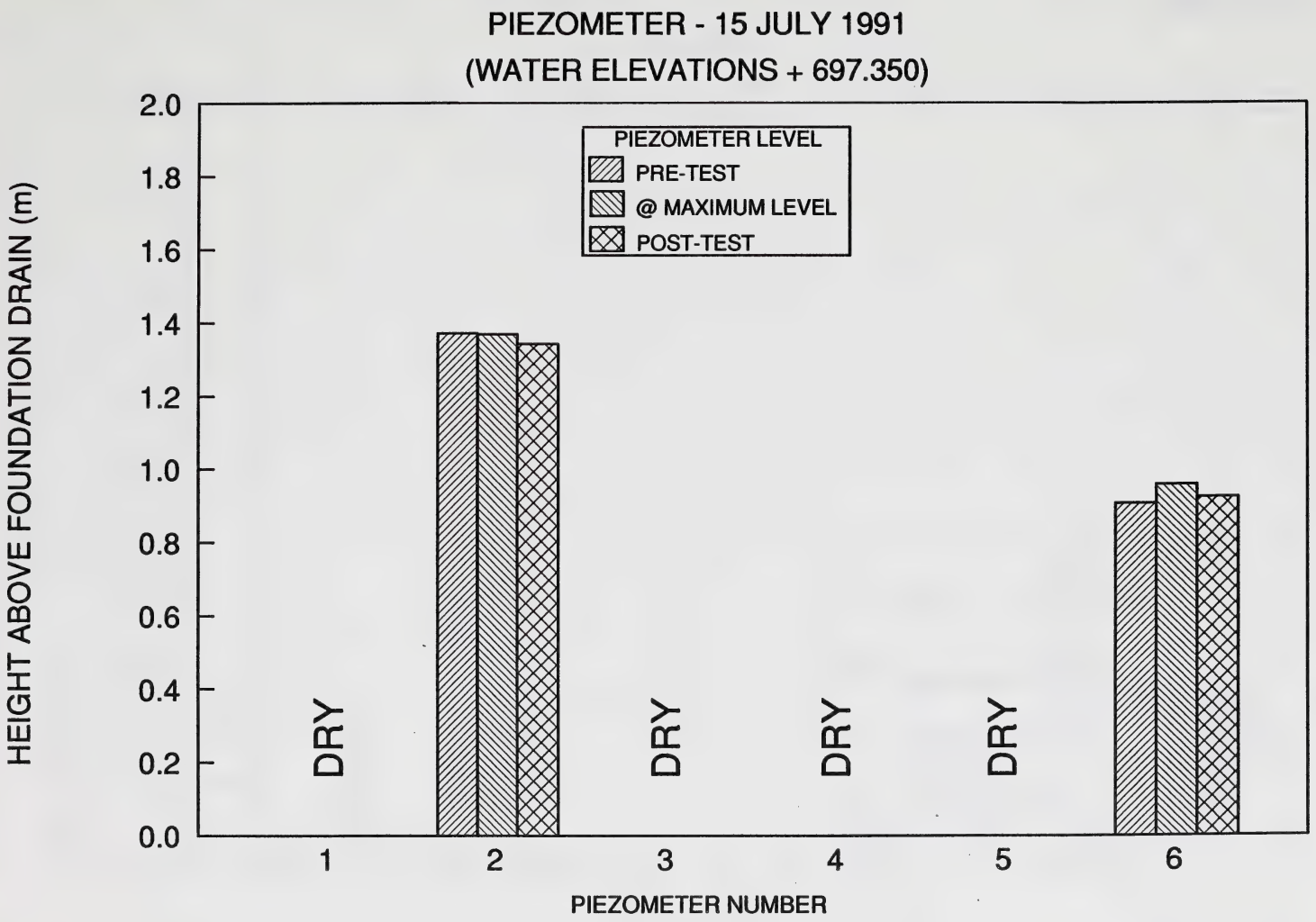
PIEZOMETER - 15 JULY 1991
(WATER ELEVATIONS + 697.350)
HEIGHT ABOVE FOUNDATION DRAIN (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
PIEZOMETER LEVEL
PRE-TEST
@ MAXIMUM LEVEL
POST-TEST
DRY
DRY
DRY
DRY
1
2
3
4
5
6
PIEZOMETER NUMBER

Figure B22

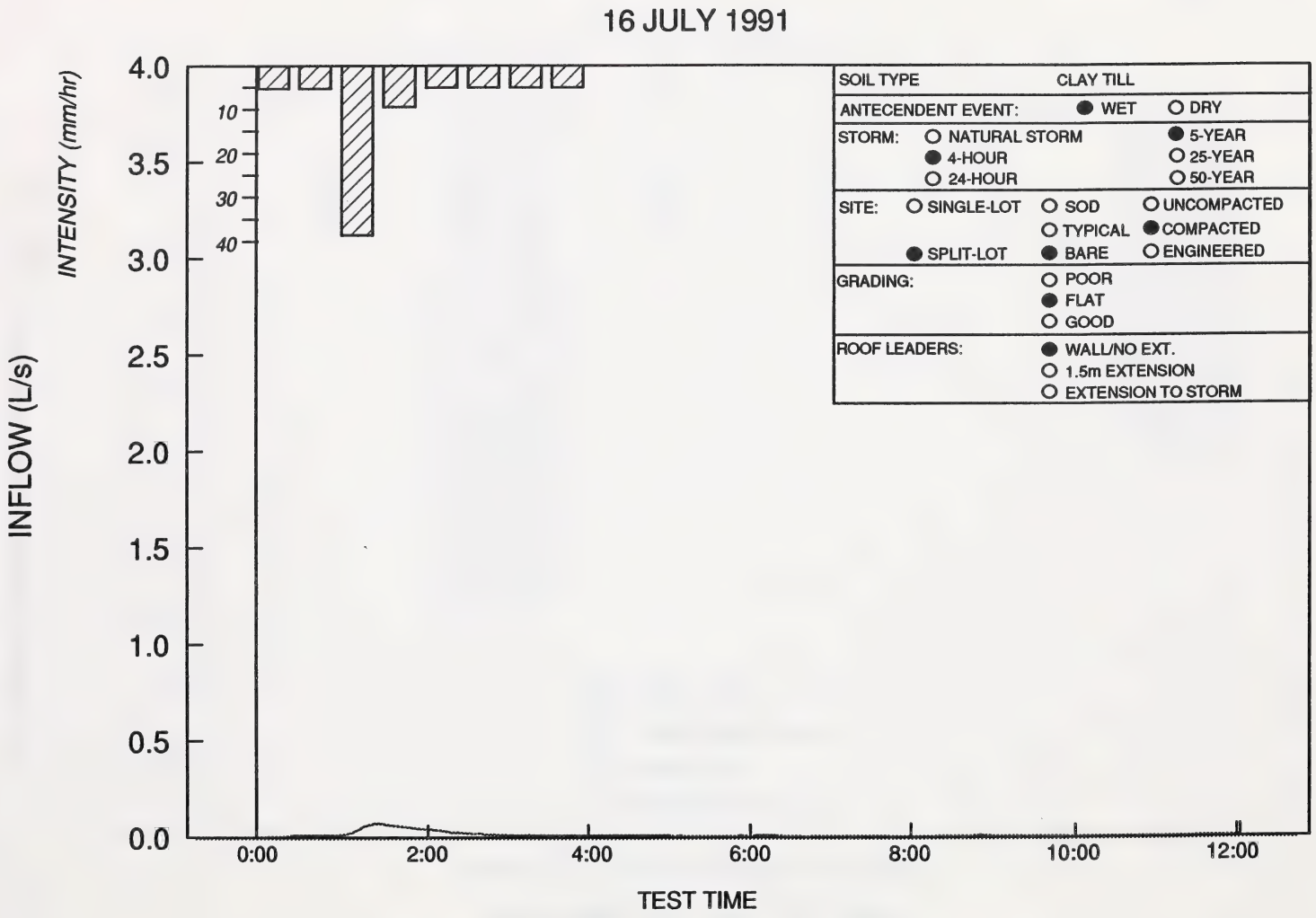
16 JULY 1991
INFLOW (L/s)
INTENSITY (mm/hr)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10
20
30
40
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: ● WET ○ DRY
STORM: ○ NATURAL STORM ● 5-YEAR
● 4-HOUR ○ 25-YEAR
○ 24-HOUR ○ 50-YEAR
SITE: ○ SINGLE-LOT ○ SOD ○ UNCOMPACTED
○ TYPICAL ● COMPACTED
● SPLIT-LOT ● BARE ○ ENGINEERED
GRADING: ○ POOR
● FLAT
○ GOOD
ROOF LEADERS: ● WALL/NO EXT.
○ 1.5m EXTENSION
○ EXTENSION TO STORM

Figure B23

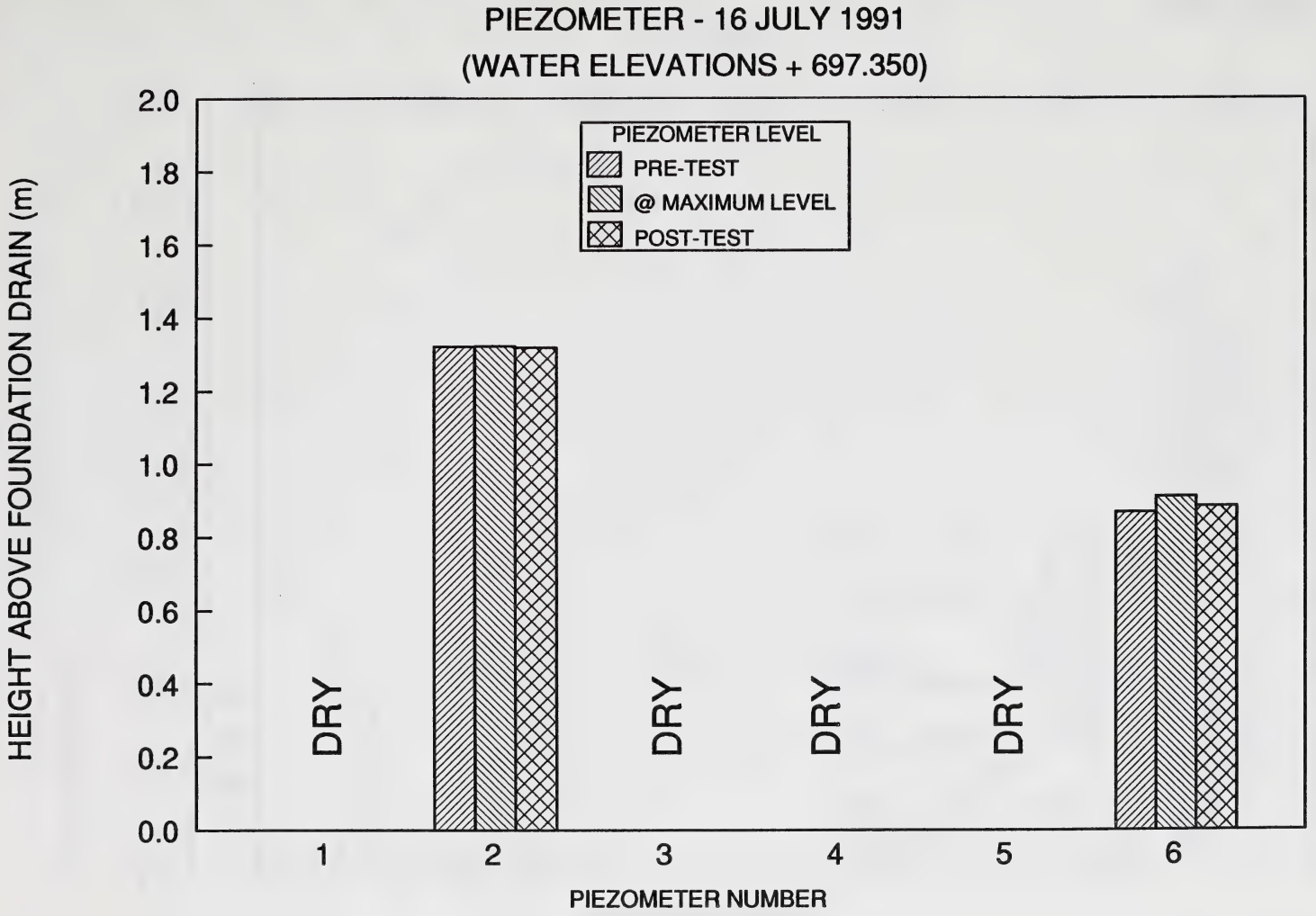
PIEZOMETER - 16 JULY 1991
(WATER ELEVATIONS + 697.350)
HEIGHT ABOVE FOUNDATION DRAIN (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
PIEZOMETER LEVEL
PRE-TEST
@ MAXIMUM LEVEL
POST-TEST
DRY
DRY
DRY
DRY
1
2
3
4
5
6
PIEZOMETER NUMBER

Figure B24

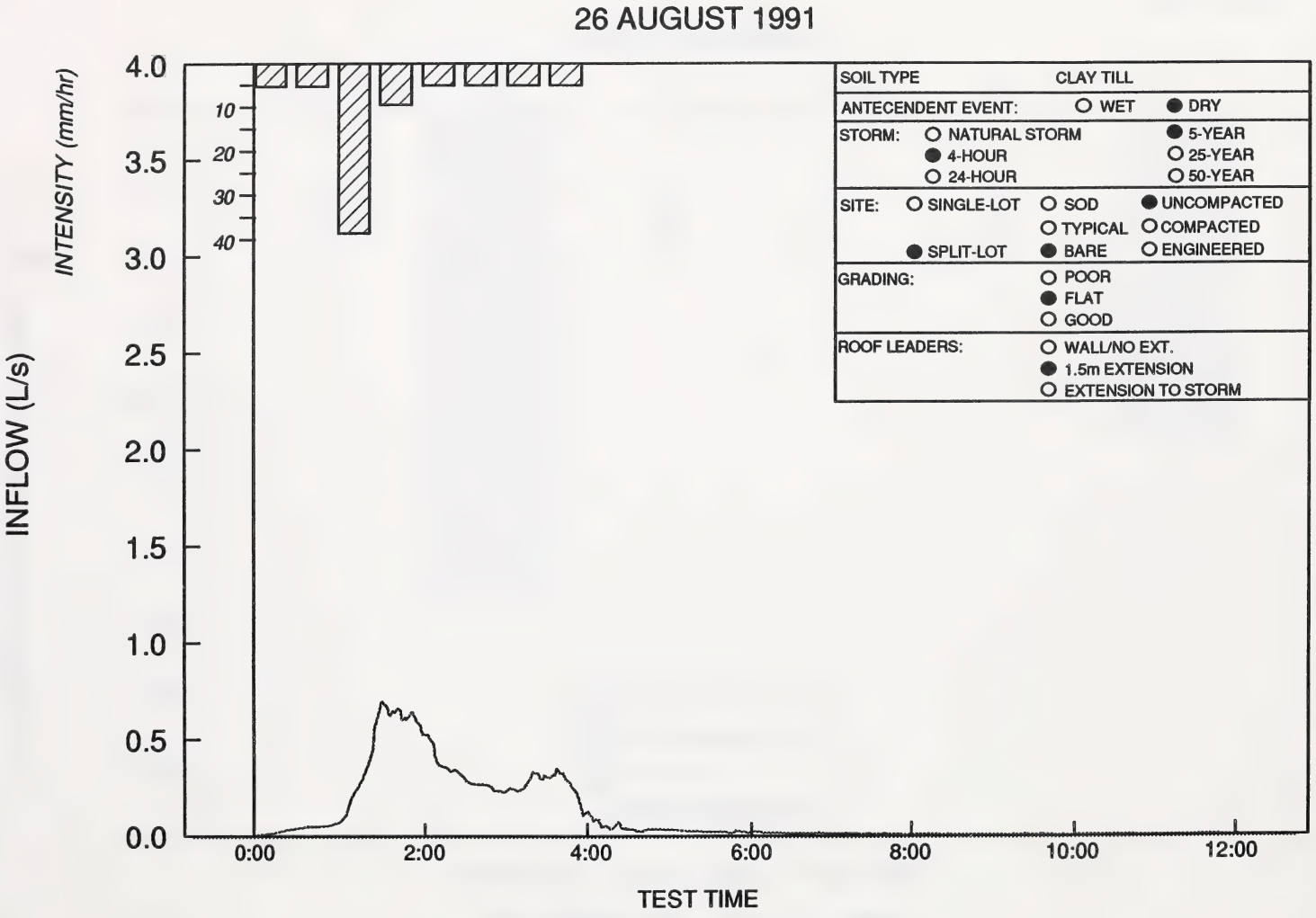
26 AUGUST 1991
INFLOW (L/s)
INTENSITY (mm/hr)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10
20
30
40
0:00
2:00
4:00
6:00
8:00
10:00
12:00
TEST TIME
SOIL TYPE CLAY TILL
ANTECENDENT EVENT: O WET ● DRY
STORM: O NATURAL STORM ● 4-HOUR O 24-HOUR
● 5-YEAR O 25-YEAR O 50-YEAR
SITE: O SINGLE-LOT ● SPLIT-LOT
O SOD O TYPICAL ● BARE
● UNCOMPACTED O COMPACTED O ENGINEERED
GRADING: O POOR ● FLAT O GOOD
ROOF LEADERS: O WALL/NO EXT. ● 1.5m EXTENSION O EXTENSION TO STORM

Figure B25

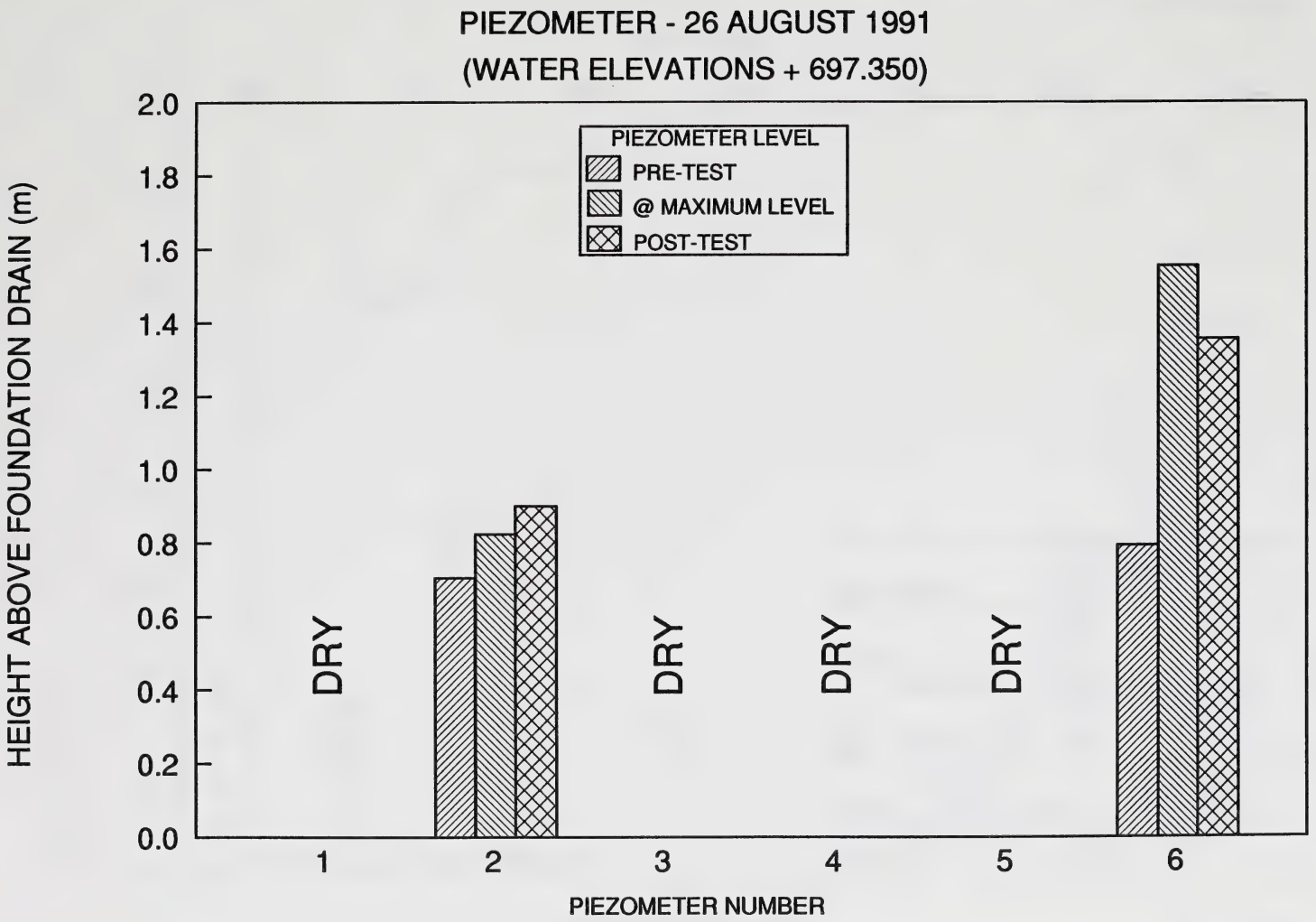
PIEZOMETER - 26 AUGUST 1991
(WATER ELEVATIONS + 697.350)
HEIGHT ABOVE FOUNDATION DRAIN (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
PIEZOMETER LEVEL
PRE-TEST
@ MAXIMUM LEVEL
POST-TEST
DRY
DRY
DRY
DRY
1
2
3
4
5
6
PIEZOMETER NUMBER

Figure B26

28 AUGUST 1991

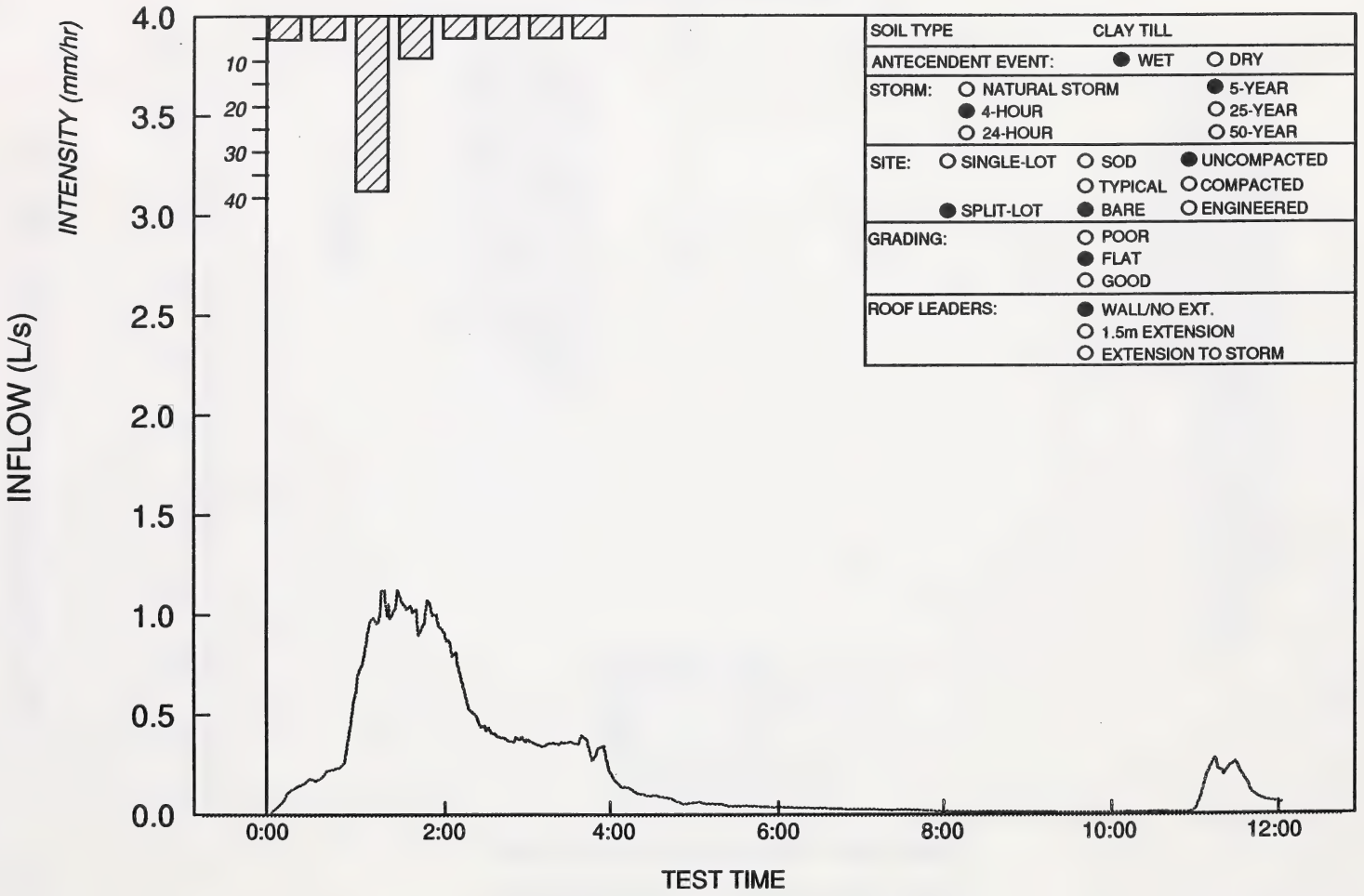

Figure B27

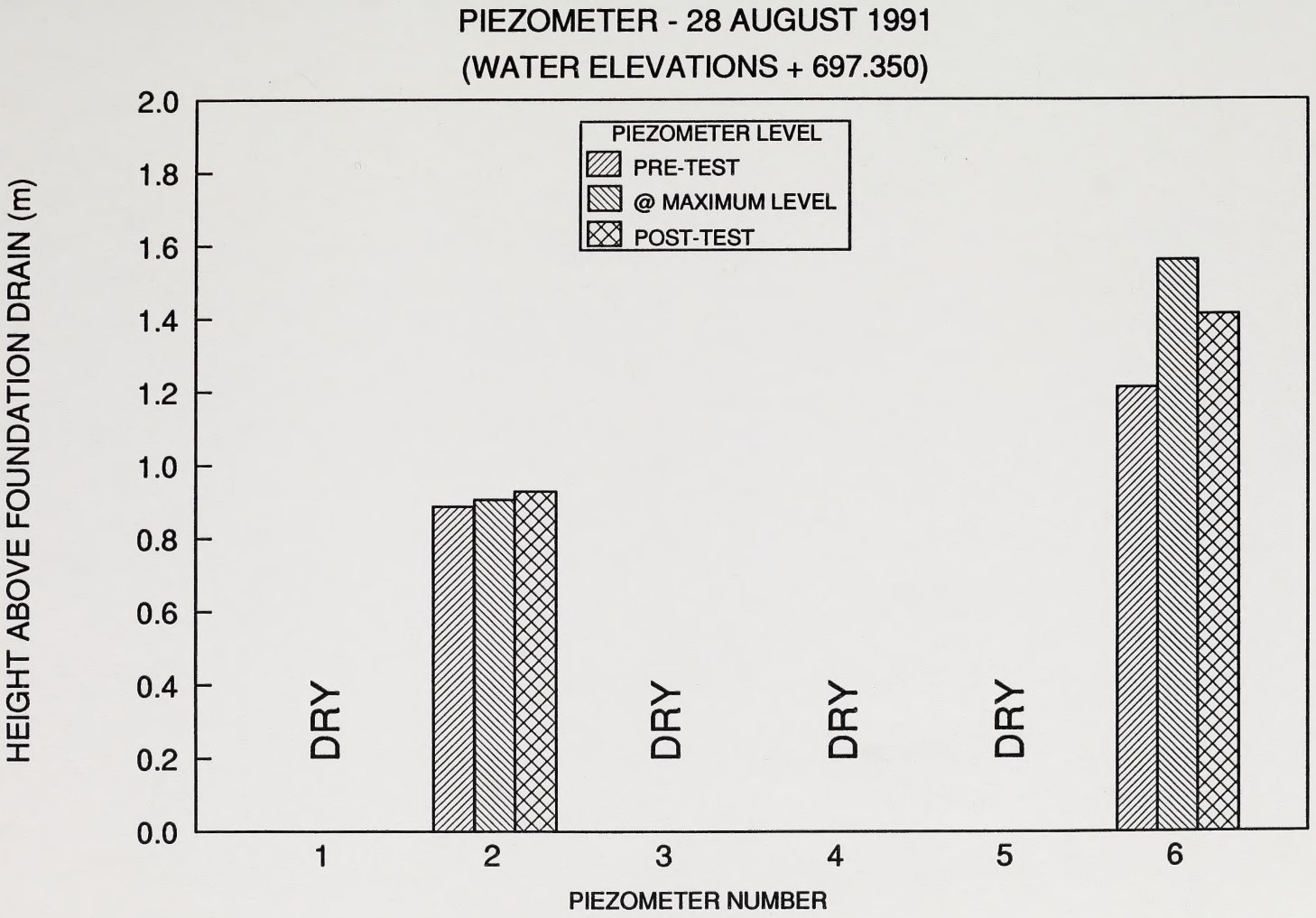
PIEZOMETER - 28 AUGUST 1991
(WATER ELEVATIONS + 697.350)
HEIGHT ABOVE FOUNDATION DRAIN (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
PIEZOMETER LEVEL
PRE-TEST
@ MAXIMUM LEVEL
POST-TEST
DRY
DRY
DRY
DRY
1
2
3
4
5
6
PIEZOMETER NUMBER

Figure B28

N.L.C./B.N.C.
3 3286 50150 1874